

Blockchain and Distributed Autonomous Community Ecosystems: Opportunities to Democratize Finance and Delivery of Transport, Housing, Urban Greening and Community Infrastructure

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Mineta Transportation Institute

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Report 22-34

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July 2022

A publication of the
Mineta Transportation Institute
Created by Congress in 1991
College of Business
San José State University
San José, CA 95192-0219

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. 22-34	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Blockchain and Distributed Autonomous Community Ecosystems: Opportunities to Democratize Finance and Delivery of Transport, Housing, Urban Greening and Community Infrastructure		5. Report Date July 2022	6. Performing Organization Code
		8. Performing Organization Report CA-MTI-2165	
7. Authors William Riggs Vipul Vyas Menka Sethi		10. Work Unit No.	
9. Performing Organization Name and Address Mineta Transportation Institute College of Business San José State University San José, CA 95192-0219		11. Contract or Grant No. ZSB12017-SJAUX	
		13. Type of Report and Period Covered	
12. Sponsoring Agency Name and Address State of California SB1 2017/2018 Trustees of the California State University Sponsored Programs Administration 401 Golden Shore, 5th Floor Long Beach, CA 90802		14. Sponsoring Agency Code	
		15. Supplemental Notes	
16. Abstract This report investigates and develops specifications for using blockchain and distributed organizations to enable decentralized delivery and finance of urban infrastructure. The project explores use cases, including: providing urban greening, street or transit infrastructure; services for street beautification, cleaning and weed or graffiti abatement; potential ways of resource allocation ADU; permitting and land allocation; and homeless housing. It establishes a general process flow for this blockchain architecture, which involves: 1) the creation of blocks (transactions); 2) sending these blocks to nodes (users) on the network for an action (mining) and then validation that that action has taken place; and 3) then adding the block to the blockchain. These processes involve the potential for creating new economic value for cities and neighborhoods through proof-of-work, which can be issued through a token (possibly a graphic non-fungible token), certificate, or possible financial reward. We find that encouraging trading of assets at the local level can enable the creation of value that could be translated into sustainable "mining actions" that could eventually provide the economic backstop and basis for new local investment mechanism or currencies (e.g., local cryptocurrency). These processes also provide an innovative local, distributed funding mechanism for transportation, housing and other civic infrastructure.			
17. Key Words Blockchain, Cryptocurrency, Tokens, transportation, Urban greening, Infrastructure, Housing, Municipal services		18. Distribution Statement No restrictions. This document is available to the public through The National Technical Information Service, Springfield, VA 22161.	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 76	22. Price

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DOI: 10.31979/mti.2022.2165

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KEY TERMS

Fiat Currency – a government-issued currency such as the U.S. dollar or the Euro supported by the stability of the government, not a physical commodity, such as gold or silver.

Blockchain – a distributed database storing information digitally without a trusted third-party. The decentralized system provides data storage security, instant processing, and reduces the cost of a transaction. Blockchains use is best known, but not limited to, cryptocurrency systems, such as Bitcoin.

Cryptocurrency – a virtual currency, such as Bitcoin, generally issued by non-governmental parties, secured by cryptography. A cryptocurrency usually utilizes a distributed ledger blockchain technology.

Bitcoin – (see cryptocurrency.)

Stablecoin – a class of cryptocurrencies providing price stability through a reserve asset. Stablecoins attempt to combine the advantages of cryptocurrencies known for secure and instant transactions with the stability and familiarity of fiat currency.

Distributed Autonomous Organization (DAO) – a blockchain-based system coordinated with a set of self-executing rules for a public, independent, and decentralized blockchain.

Smart Contracts – a self-executing agreement between buyer and seller stored in lines of code and incorporated into the distributed, decentralized blockchain system. The trackable and irreversible code controls the implementation of transactions among anonymous parties without centralized or third-party enforcement.

DeFi (Decentralized Finance) – a new financial technology aiming to lessen the control of banks and institutions on money and financial products. DeFi is based on secure distributed ledgers, similar to blockchain.

Ledger – a record-keeping system for financial data for each debit or credit transaction, validated by a trial balance.

Distributed Ledger – a decentralized database providing data security through sharing and synchronizing across multiple computers. Any change of the ledger instantly alters its copies distributed between all participants, which prevents cyber-attacks and fraud more often associated with a single point of failure of a centralized ledger.

Scrip – a substitute or alternative to legal tender that provides the bearer to hold a credit or other forms of scripts.

Service inventory – Potential for delivering services, contracts, or infrastructure; basic function of government. Potential to assign rights to perform this work in a way that is transparent and trackable for a range of municipal activities and services.

Node – a user or computer within a blockchain architecture or network; each node in the network operates independently and has an independent, full, or partial copy of the order or ledger (see distributed ledger).

Transaction – blockchain operates on a series of rules to carry out operations; a transaction is the smallest building block of a blockchain system; it contains the information that informs tasks and entries / records into the system.

Block – a structural segment of data on the network; the block structure allows it to be distributed efficiently to the various nodes across a network.

Chain – the sequence or ordering of blocks on a ledger or network.

Miners / mining – the nodes / individuals and process of completing actions on a blockchain network; usually completed by verification / validation actions before a block is added to the blockchain sequence / distributed ledger.

Consensus / Consensus Protocol – the rules for engagement in the blockchain network; protocols for behavior and rules for how process flow arrangements work.

Non-Fungible Token (NFT) – a unique metadata asset on a blockchain that cannot be traded or exchanged equivalently, as it is distinguished from others. NFTs are unlike cryptocurrencies (fungible tokens), which are identical.

Executive Summary

Many global cities face crumbling transportation infrastructure, housing shortages, and insufficient capacity to provide municipal services. There are vast areas of poorly utilized urban space that represent blight and low-value use. Further, there is little opportunity to empower individual citizens to express ownership of their own environments—providing solutions to the systemic problems such as climate change and homelessness (literally) within their own backyards—despite many neighborhoods and local organizations having the potential to function as evolved forms of distributed autonomous organizations (DOAs) and self-fund / create what they need or desire.

Autonomous Community Ecosystems (ACEs) harness new technologies and create an opportunity to think about how citizens and organizations can create change in their own streets and backyards to accelerate how government infrastructure and services have traditionally been delivered. Decentralized finance (commonly referred to as DeFi) has recently been discussed as a part of blockchain-based cryptocurrencies—Ethereum, Bitcoin, and Dogecoin—yet the principles of decentralized and independent software platforms that allow for lending and finance have much broader application potential. Many brokerages, exchanges, and banks are exploring offerings using decentralized financial instruments that allow for more flexible financing.

This report investigates and develops specifications for using blockchain and distributed organizations to enable decentralized delivery and to finance urban infrastructure. The project uses cases include:

1. providing urban green space development,
2. street or transit infrastructure,
3. services for street beautification,
4. cleaning and weed or graffiti abatement,
5. potential mechanisms for resource allocation of land use rights,
6. Accessory dwelling units (ADUs) homeless shelter and housing,
7. conservation efforts;
8. and urban blight restoration and greening.

These use cases are contemplated based on four core benefits of blockchain technology; it can help:

1. Build Trust with Citizens
2. Assign Disaggregated Rights More Transparently
3. Reduce Costs & Improving Efficiency
4. Protect Sensitive Data While Providing Validation

The general process flow for blockchain architecture involves: 1) the creation of blocks (transactions); 2) sending these blocks to nodes (users) on the network for an action (mining) and then validating that that action has taken place; and 3) adding the block to the blockchain. The blockchain process can also capture the creation of new economic value by capturing and tracking work through the discrete transactional activity associated with the works (for example, individual work steps from digging a ditch to pouring concrete to installing drainage). The discrete capture of work creates a proof of that work. The value created from that work can be reduced to a token which represents the completion of a specific work stream. Such tokens can be potentially reduced to a non-fungible token (NFTs), certificates, or other possible financial rewards. The tokens represent the value created from the work and can form the basis for alternative scrip or currency to promote decentralized financial activity and hyper local economic activity.

Work can create value or work can create assets that create value of both. For example, installing rainwater capture cisterns creates valuable water reserves. The maintenance of those cisterns also creates value by enhancing the usability of those cisterns. The work associated with the creation of these assets or other works can be captured with a high degree of confidence on a blockchain. The captured value can then backstop the value of the tokens issued on the blockchain based on the verified work and verified working asset. The blockchain based token in this model brings to represent real value created.

This creation of value at the local level can be reduced to a token that can then function as a local scrip or currency that can encourage local economic activity and keep more wealth within communities. Another example of verified work that can create value would be community generated carbon offsets which could trade on local, national, or even international carbon credit exchanges to offset pollution. Local communities can invest in verifiable offset activity that can then be monetized. These activities can be reduced to local tokens that can then be converted to fiat currency such as US dollars. This offset activity could be in the form of community funded solar projects, tree planting for carbon sequestration, urban greening, reflective roof construction, or other carbon offsetting activities. Community member labor, land, and other suboptimally used resources can be harnessed to create wealth in the community in ways that have not been previously contemplated. With a clear workflow, required steps, required validation, and other

protocols in place on the community blockchain; decentralized and distributed activity can be effectively coordinated to produce value for the individual community member and the community as-a-whole. Value generating activities could extend to other activities such as provisioning of homeless services, ease of auxiliary dwelling unit permitting (which may be encouraged by municipalities), litter clean up, graffiti clearing, and other municipal services that can be performed by individuals through what would effectively be conferred micro contracts between the city and those individuals. This kind of financial ecosystem warrants more exploration.

New forms of exchange for transport and housing infrastructure, energy, and many other functions that happen at the neighborhood level could now be possible. A municipal exchange platform could provide the se ecosystems and build on the process flows defined herein with simple ways of creating local economies, facilitating transactions, issuing rights and conferring contracts.

Local governments should pay close attention to these potential developments. Whether municipal or regional governments want to create such ecosystems or not, Groups of individuals could create such platforms as well. Neighborhoods could establish autonomous community ecosystems (ACEs) at the hyper- local level and enable transactions in new currencies and investment in infrastructure and services in a way that government cannot deliver. It is our hope that this would lead to smarter and more transparent ways of building and running cities with either nominal and reluctant involvement from city governments or enthusiastic and coordinated support.

1. Introduction

Around the world, many governments have failed to serve their citizens at the most fundamental level, where cities are unreliable at delivering the most basic services, from cleaning streets to delivering on-time transit service or paving potholes, to building or allowing the development of the appropriate supply of housing to meet demands. Each of these cases has led to frustration and an erosion of public trust that feeds discontent in our cities and neighborhoods.

The public has an implicit social contract with their cities for this infrastructure, and the expected services provided, but cities are “falling down on the job”. Public works departments spend billions of dollars providing services that may or may not align with what individual citizens and neighborhoods want. In 2021 alone, the value of public construction projects in the U.S. was \$346.2 billion according to the U.S. Census Bureau (1), yet frequently the benefit of these expenses is not visible to taxpayers. Moreover, the World Bank estimates over \$1 trillion was wasted in global procurement that could have been put towards more sustainable and green infrastructure (2).

The public has lost confidence in where, how, and how wisely resources are allocated. The effectiveness, efficiency, and competence of government is perceived to be low.

This loss of confidence creates an opportunity for innovation by building better ways for individual citizens to participate in city building, particularly since the most basic governing principles rely on DAOs and collecting tribal interests into coherent rule-abiding networks. In any social contract or contract otherwise, there is the assignment and management of rights; yet communities have real needs that a new category of technology that assigns rights, trusts and verifies work. This new space / category of technology allows DOAs to evolve into Autonomous Community Ecosystems, where urban inefficiencies and needs can be identified, addressed and paid for at the most basic level of how / where we live—our neighborhoods (as if SeeClickFix me t TaskRabbit me t Kiva / Kickstarter).

This report explores how citizens and neighborhoods can use blockchain technology and cryptocurrency tools to bring better infrastructure solutions directly to neighborhoods. Smarter government. In sum:

Today: public works spends close to \$350 billion in the U.S. and deliver an insufficient product to solve urban problems;

Tomorrow: cities and citizens might be able to self-organize, create their own organizations to solve urban problems, and fund these using fiat or new crypto currencies.

This document outlines a future where cities can work better and where new organizations and financial systems can reshape streets and land use and put new value on what individual neighborhoods and groups want to see in the places where they live, work, and play. This can be

- Commercial agreements and contracts for street / municipal infrastructure: street sweeping; pickup; garbage collection; bike / scooter system rebalancing
- Land Rights Allocation and Development for parklets, on-street dining, and housing / homelessness services.

Blockchain technology allows for these distributed systems to work so that they can be autonomous, while rebuilding trust and providing more transparency in systems. While some might argue that this can be done with simple anonymous databases, there are four distinct advantages to using blockchain, which include the following that are outlined in Table 1:

1. Benefit No. 1: Building Trust with Citizens
2. Benefit No. 2: Assigning Disaggregated Rights More Transparently
3. Benefit No. 3: Reducing Costs & Improving Efficiency
4. Benefit No. 4: Protecting Sensitive Data While Providing Validation

This report first provides some key terms and ideas around blockchain technology and DAOs. It provides a background on what the technology is, how it has been used in the past and how it relates to government and ultimately to cities, introducing the idea of an autonomous community ecosystems (ACEs) as a new category of transactional technology tools. Following this, a general process flow for municipal blockchain applications is provided along with a conceptual map for a decentralized finance framework. A section on specific applications follows and, after that, conclusions and broader applications are considered.

Table 1. The Benefits of Blockchain for Cities and Neighborhoods

<p>Benefit No. 1: Building Trust with Citizens</p>	<p>A key feature of blockchain-based solutions is transparency through decentralization, allowing participating parties to see and verify data. A blockchain solution for some citizen services could allow for independent verification of governmental claims. For example, the governments of Sweden, Estonia, and Georgia are experimenting with blockchain-based land registries, enabling multiple parties to securely hold copies of the registry. This model could help quickly resolve property disputes or prevent them altogether. When citizens and governments share access to records, the potential for distrust decreases.</p>
<p>Benefit No. 2: Assigning Disaggregated Rights More Transparently</p>	<p>Blockchain allows for the assigning of rights in an efficient and inclusive way that is rules- based and moves beyond the discretionary way many municipal decisions are made and permits assigned. It allows for a clear approvals chain and can enable disaggregated ways of validating rights / work assignment as well as illustrated proof that work / rights have been conducted according to desired specification. This can be done through smart contracts with proof / conference of a right distributed with a digital non-fungible token (NFT).</p>
<p>Benefit No. 3: Reducing Costs & Improving Efficiency</p>	<p>Government agencies must fulfill their mission while responsibly managing scarce resources. For government leaders walking this budget tightrope, blockchain may be a much- needed lifeline. In the right context, blockchain solutions could reduce redundancy, streamline processes, decrease audit burden, increase security, and ensure data integrity.</p> <p>To further illustrate how blockchain solutions could increase efficiency, consider the federal government’s ongoing challenge with reconciling intragovernmental transfers. At any given time, there are trillions of dollars in unreconciled funds in the federal budget. The process of reconciling these funds is time- consuming, expensive, and creates budget uncertainty. A payment and accounting system that used blockchain could provide a permanent audit trail and facilitate faster reconciliation.</p>
<p>Benefit No. 4: Protecting Sensitive Data While Providing Validation</p>	<p>Many private sector companies and government agencies, whether in the transportation / mobility space, mobile phone, or social media / gaming space, keep sensitive data that could provide personally identifiable information (PII) and sensitive location data. Breaches of this data have become a reality in today’s digital world. The full names, Social Security numbers, birthdates, addresses, and driver’s license numbers of 143 million Americans were exposed in the 2017 Equifax database breach. Just two years earlier, more than 20 million records of past and present government employees were stolen from databases maintained by the Office of Personnel Management.</p> <p>As the default record keeper for society, governments are large targets for hackers. Rather than accept such attacks as the cost of</p>

	<p>doing business in the information era, blockchain data structures could mitigate or avoid them. Such data structures harden network security by reducing single-point-of-failure risk and can make attempting a breach prohibitively challenging.</p> <p>Government agencies, such as the Department of Homeland Security (DHS), are getting serious about blockchain applications in cybersecurity. DHS is funding blockchain startups to conduct research and development and explore new approaches to cybersecurity. According to a DHS official, “blockchain technologies have the potential to revolutionize the way we manage online identity and access the internet; this R&D project will help bring this potential closer to reality.” The same technology can not only be used to prevent personally identifiable information leaks, but can be used to protect sensitive location data while providing validation of regulatory compliance / standards.</p>
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2. Background

Many global cities face housing shortages, crumbling infrastructure and insufficient capacity to provide municipal services. There are vast areas of poorly utilized urban space that represent blight and low-value use. Further, there is little opportunity for individual citizens to be empowered and express ownership of their own environments—providing solutions to the system’s problems such as climate change and homelessness within their own backyards. In sum, governments don’t do a great job of leveraging:

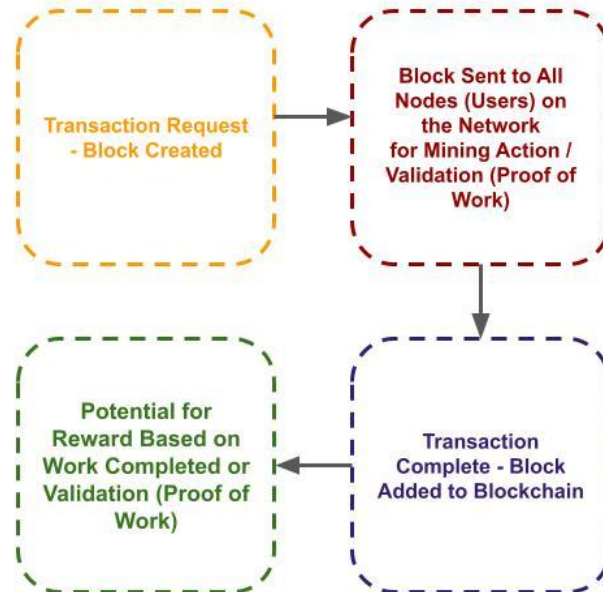
- Space
- Capital
- Human capacity

At same time, blockchain technology offers a way to think differently about how cities can approach providing transportation and myriad pieces of infrastructure or municipal service in a more efficient, cost-effective and transparent way. This can help reintroduce trust in government, which has continued to erode over the last half a century (9); yet a majority still believe that government has a role in security, disaster response, food and medicine safety, economic growth, and maintaining infrastructure (10). Blockchain, at its most fundamental level, can help by providing a digital way of structuring and ordering tasks in a chain that is distributed and decentralized to create greater levels of security, efficiency, and trust across disciplines.

Most social institutions require trust to operate, but trust is becoming increasingly scarce. Trust is reinforced by clear, established, and predictable rules; agreed-upon enforcement mechanisms; and courts of law to adjudicate disputes and arbitrate between competing interests when disagreements occur. Per Gallup, trust in government has fallen; therefore, mechanisms that increase trust should be actively explored by governments at all levels (11). Trust has especially eroded in the context of the COVID -19 pandemic, the broader flow of information from decentralized sources, and the retrospectively unpopular policies over the past 20 to 30 years in Western societies.

At its most basic level, blockchain is a combination of nodes on a network with rules that define the work occurring in that network. This is illustrated by the general flow in Figure 2, where blocks are created (which represent transactions) that are then sent to nodes on the network for work and proof of work. After the work is completed, a record of the work is added to the entire chain. Proof of work can be issued through a token (possibly a graphic non-fungible token), certificate or a financial reward.

Figure 2. A General Blockchain Process



The general process flow for this blockchain architecture involves: 1) creation of blocks (transactions); 2) sending these blocks to nodes (users) on the network for an action (mining) and then validation that that action has taken place; and then 3) adding the block to the blockchain. It also involves potential for creating new economic value through proof of work which can be issued through a token (possibly a graphic non-fungible token), certificate or possible financial reward.

To be clear, blockchain is not Bitcoin. This a common point of confusion. Digital currencies such as Ethereum, Bitcoin, and Dogecoin, rely on the principles of decentralized and independent software platforms to allow for lending and finance, but the principal has significant opportunities for application in cities to improve the function of services delivery and local economies.

2.1 History of Blockchain Applications

Blockchain technology has been contemplated as a mechanism to create trust by obviating the need for trust in people or people-based institutions to the degree it is required to exist today. By putting into code the rules, enforcement, and adjudication of disputes, blockchain can reduce the need for trust in people or collections of people in the form of institutions that are no longer as necessary. The mutually- agreed- upon code executes behaviors that may have previously relied on trustworthy actors to execute. For example, municipal contracting and change order processes can be tracked, administered, and inspected based on a predetermined process that is reduced to computer code versus a process that requires and assumes that all participants behave as good actors. How contracts are awarded based on consensus voting among designated participants

would be tracked and visible. Events, such as issuing requests for proposals, proposal submissions, submissions reviews, change order submissions, change order approvals, change order execution, etc. can also be openly tracked via code.

In addition, blockchain can also standardize, automate and make more predictable workflows that are required for proper execution of processes. As in the example above regarding municipal contracting, steps may have enforced sequences, decision- making points and feedback loops that can be captured and enforced through the blockchain's definition.

Blockchain technology has evolved from a series of developments spanning several decades. The first stage of development was hashing, a core part of cryptography. Cryptography is the science of securing messages so that only the sender and receiver are able to decode and understand the message. The Little Orphan Annie decoder ring in the movie *A Christmas Story* is a simple example of cryptography (12).

Hashing involves creating a hash or hash value, and it has three key elements:

1. the message or "input,"
2. a hash function that encodes the input into an indecipherable set of new characters that only someone else who has the hash function can decode, and
3. the hash value itself, which is the "secret code."

Simply put, hashing involves taking a message or input and converting that input into a string of characters, called a "hash value," using an encoding algorithm called "the hash function." To decode that hash value, you would need the hash function, revealing the "secret message." Hashing is the first key piece of blockchain technology. The next key development was the concept of the blockchain itself.

In 1991, Stuart Haber and W. Scott Stornetta invented a secure block- based ledger to track and validate the execution and timestamps of digital documents. They observed that accurate and trustworthy record- keeping is critical and, as this record- keeping moved from paper to digital medium, mechanisms would be needed to validate their accuracy and authenticity. They were attempting to create a type of automated notary. Haber and Stornetta foresaw the rise of digital documents and wanted to ensure that information such as when something was sent, approved, signed-off on, etc. was tamper proof, guaranteeing the security, accuracy, and trustworthiness of this digital document journey. They divided the digital journey into "blocks, " the sequence of which was the "block chain." A document may begin by being received and then sent back out again. The receipt and the send events represent two different events that would be captured as two separate "blocks;" this sequence of events would be the chain.

Haber and Stornetta used hashing to encode, for example, that a digital document may have been received. The date of receipt of the digital document would be captured as an input, put through the hashing function, and converted into a hash value. This hashing process encoded the date of receipt into a hash, and, if the document were sent to a third party, a second transaction would occur. The send date becomes a new event that requires capturing and encoding.

After contemplating a series of steps that could be used to capture the journey of a digital document, Haber and Stornetta linked these blocks together by making the input of the second block include *both* the send date information *and* the hash value of the previous block in the chain, which was the “date received” block. This ensured the integrity of the entire chain, as now the second block’s encoded message contained both the send date information and a reference to the previous “received date” block together in a new encrypted hash. Simply put, the message or input of the new block in the chain would include the new message (in this case “date sent”) and the hash of the previous block combined together. With this mechanism, each step in the chain references the prior step to make a connected chain. This chain of blocks is visible to all stakeholders, and the hashing make each step difficult to tamper with. With this new “blockchain,” transaction events could be securely captured, stored, and linked together in logical sequences.

To summarize, a blockchain has a few key attributes. First, the blockchain can help define a sequential flow of transactions or events; it represents a flow. Each block holds information captured for each transaction. Using the previous example, in a document that requires multiple approvals in a sequential order; the first block may represent the first party’s receipt of the document. In that block, a unique identifier or hash is used to denote the creation and existence of the block. The hash includes information about the transaction, such as its receipt date. The next transaction could be the sending of the document on to the next document reviewer. The hash for this next block would encrypt both the new send date and the hash of the previous block.

In 1992, a concept called Merkle trees enabled easier and more efficient tracking of multiple entries. As countless transactions occur on a blockchain, Merkel trees were created to capture all of the hashing activity. The particular mechanism of Merkel trees is not important for this discussion, but they were important in making the technology scalable so that a large number of transactions could be written to the blockchain.

In the early 1990s, the need for securing digital information exchange was not perceived to be critical, and the patent for blockchain and its associated technologies lapsed without much interest in 2004. The next stage of blockchain technology’s evolution occurred through a series of publicly issued whitepapers.

The next evolution in technology occurred soon after the original blockchain patent expired. This evolution was the concept of universal inspectability of the blockchain by key stakeholder parties. In August of 2004, Hal Finney developed a concept called Reusable Proof of Work

(RPoW) to track transactions and to enable a broad universe of participants to write to the blockchain. Finney's innovation also allowed the blockchain to be distributed ownership of a token using a set of central trusted servers. Finney's central idea was that each participant in the blockchain could be issued a token that would confer rights and access to the blockchain. Finney's concept used a "trusted server" or computer that all participating parties could validate. The token was originally conceived as a way to confer participatory rights to the blockchain. The primary role of tokens was to exchange access to the blockchain. These tokens could also be exchanged across participants.

Finney's innovation enabled broad participation of many parties on a blockchain, transforming the technology from being narrowly usable by a limited number of people associated with a transaction to a broad universe of people that could collectively participate.

In 2008, a person or persons named Satoshi Nakamoto published a whitepaper describing a peer-to-peer network with a secure, decentralized ledger. This meant that a blockchain could also be distributed and accessed across the various stakeholders. With this move, the blockchain could be managed in a decentralized manner with no single owner; instead, peer consensus and management would be used. Trust, theoretically, would increase because no one authority could then manipulate the transaction history. Decisions could also be made using a consensus voting mechanism, which would be open and transparent. With a decentralized database, for example, instead tracking account balances like a typical bank, a blockchain could create the opportunity to decentralize control of that "database of record," where copies of that database was shared with all participants. Simply put, all interested parties or stakeholders can hold a copy of the database. When a transaction is completed in the chain, a new block is created in all of the databases held by stakeholders associated with the blockchain. A new entry is made in all of the distributed databases or "ledgers." With regard to consensus building, the peer-to-peer innovation effectively made "board meetings" with regard to how the blockchain should be governed, modified, and managed—transparent and public. Each participant in the blockchain could vote on changes in an open and transparent manner. For example, if signature images needed to be captured going forward, a consensus could be reached to modify the blockchain process to ensure the capture of that information.

With this collection of technologies, cryptocurrencies became possible. In 2009, the first blockchain block for bitcoin was created or "mined" and transferred to Hal Finney. Cryptocurrencies leverage all of the above concepts to create "tokens" and enable the transfer of tokens between individuals. Instead of using blockchain technology to secure and track digital documents, the technology was applied to the tokens concept, which represented a form of digital currency. The transfer of those tokens between individuals could be tracked in what look and feel like payments. Tokens were transformed from being a mechanism to validate participation and access a blockchain to a representation of value. The core technologies were redirected from their original contemplated uses to facilitate the rise of cryptocurrencies.

However, cryptocurrencies were limited in their application of the underlying blockchain technology. The next critical innovation came in 2013 with Vitalik Buterin's conception of smart contracts as part of the Ethereum project. Smart contracts self execute a predefined set of transactions across a blockchain. Whereas, normally, blockchains are updated and modified by people (or machines at people's direction) executing the transactions, the smart contract predetermines what happens from one step to the next. Smart contracts codify the process that the blockchain is meant to securely capture and document. For example, in a smart contract, a request for a proposal may automatically enforce a deadline for submissions, route them for review, then force a consensus vote to make a decision on awarding the bid. In a traditional blockchain environment, those steps could be captured and recorded on the chain, however, with a smart contract, those steps are automatically executed and enforced, leveraging prior technologies. Peer- to-peer innovation allows all participants to see the process, which enhances trust. It also enables the smart contract to gather consensus by polling all participants and then automatically adding the next block in the chain to the distributed ledgers, once consensus is achieved.

Smart contract technology enabled the creation of non-fungible tokens or NFTs. NFTs are essentially the conveyance of a right through an agreement or smart contract. Today, NFTs are popularly used to assign rights to unique artwork. This artwork can be bought and sold among individuals. The blockchain records the creation of the art and transfer of that art to a buyer. The blockchain then tracks the resale of that art. In the case of NFTs, the smart contract defines the parameters by which the art, in this example, can be transferred and what rights are part of that transfer. Whereas blockchain primarily recorded and stored information about transactions, smart contracts added the ability to "script" terms and behaviors onto the chain to specify what happens. In other words, smart contracts specify and potentially even execute what the next block should be based on predetermined terms.

With the advent of smart contracts, smart organizations became possible. Decentralized Autonomous Organizations (DAOs) were created as the next evolution of blockchain technology. Corporates of all types from limited liability corporates to partnerships are created and governed by operating agreements that specify how the organization should be governed, how the board of directors should be constituted, and how rights should be devolved to shareholders. The operating agreement of a corporation or organization can now be reduced down to a blockchain- based smart contract. Stakeholders' votes can be taken using the peer-to-peer consensus mechanism, as an example.

With the rise of DAOs, the next stage of evolution required their governance. Autonomous Community Ecosystem (ACE) has been contemplated for this task and is described further in section 4.5.

2.2 Emerging Applications of Blockchain Technology

Governance

Government departments have operational interdependence, but function in silos. This setup impacts services' accessibility and diminishes the citizen experience. Blockchain technology can be used to break free of these silos, enhance transparency and efficiency, and oversee government corruption (if any exists). Linking data and file movement across departments via a blockchain would enhance the process' visibility and ensure that the file/data is moved ahead in real-time.

Civil Registration

The process of civil registration can be eased by applying blockchain technology to develop distributed platforms for citizen registration and to register important events, for example deaths and births, on blockchain technology. This makes citizens' records resilient, private, secure, and tamper-proof, thus, offering a wide range of benefits for multiple stakeholders.

Agriculture

Blockchain technology can reduce complexity and cost in value chains dependent on food and increase transparency by offering reliable sources and traceability from farmers to consumers. Some other viable applications of blockchain technology in agriculture include managing and recording agricultural land insurance and archives.

Defense

Data regarding the infrastructure of computer systems and infrastructure is critical to national security. Therefore, it is dispersed across various locations to restrict unauthorized modification and access. One can leverage blockchain technology to offer consensus-centric access for the distribution and modification of data access over several system resources such as data centers, hardware equipment, and networks.

Healthcare

Digitization of health records has caused a significant shift in the public health arena. However, it has often been criticized for complications regarding ethical issues and centralization. Blockchain technology has the ability to disturb public health by developing a flexible and secure ecosystem, for the exchange of electronic health records (EHRs). The technology can create transparency in the space by developing provenances for organs, blood, critical drugs, and much more. Additionally, it can prevent fraudulent doctors from practicing by scrutinizing medical licenses on the blockchain.

Justice and Public Safety

Blockchain can dramatically increase the efficiency of public safety deliverance by solving the problems of inter-agency collaboration (13) by considering certain predefined conditions to offer a common source of truth that every agency interfaces with independently. Creating a custodial chain for vital evidence is often an essential prerequisite for the admissibility of gathered evidence. Blockchain technology can help launch the source of the custodial chain for evidence like this.

Education

Educational certificates as well as faculty and student records are vital assets in the education field. Over time, these records are shared with several stakeholders, who must be reliable and trustworthy. One must also determine the source of these records with utmost accuracy. Blockchain technology can help maintain these documents safely and reliably. The technology can further simplify certificate verification and attestation and can even alter the framing of educational inclusion policy by bringing about uniformity in national metrics tracking.

Environment and Climate

A variety of emissions and environmentally oriented applications of blockchain have recently emerged, providing opportunities to use NFTs and crypto investments to reduce greenhouse gas emissions, particularly given the lack of sustainability of many initial cryptocurrencies (14–16). Some provide carbon credits based on tree planting or other offsets that have the potential to be verified by 3rd parties (14). While it is unclear if a public ledger is being used for this, a handful of companies aim to use their proceeds to directly offset through tree planting (17, 18). For example, TreeCoin is targeting the reforestation of “59,650 hectares of land [that] will provisionally be acquired for reforestation, generating a projected profit of \$1.1 billion” through sales of renewable lumber over a 23- year life cycle.

Energy

Blockchain technology can successfully be implemented to develop a marketplace for the supply of electric power. Using solar energy to generate power for the microgeneration of electricity promotes renewable sources of energy and supplements the supply of traditional power. A blockchain comprising credits can maintain a record of electricity consumption and production for every user present in the grid using smart meters. These blockchains are allocated to users for a surplus supply of power and the number of credits redeemed via power consumption, creating a hassle-free, efficient, and transparent energy market.

This also allows for the establishment of currencies or trading platforms based on energy production as opposed to consumption. Even Bitcoin has been criticized for consuming as much energy as some countries. According to the New York Times, it takes as much as nine years of

an average household's electricity to produce one coin (19). Yet other companies have been pursuing more sustainable models that install and produce energy instead of consuming it (20). While this has not been used for currency valuation, it is likely only a short time before these currency-valuation frameworks become more sustainable and are applied to the building blocks of energy production, including the rare metals used for batteries and storage applications.

Smart Cities and Building Design

Smart cities require highly compatible and appropriate technological ecosystems to be developed and function successfully (21). If systems are not able to communicate with peers due to a language difference, they can become isolated. According to literature reviews from several research papers, Blockchain is widely used in Smart City Services. For example, it can be applied to service delivery, smart contracts, and supply chain applications. Keeping this objective in mind, the development of modular architecture provides an ample growth area to optimize and local building materials and accelerate construction timelines.

2.3 Blockchain and Cryptocurrency for Cities

As previously referenced, blockchain systems are based on continuous chains of data blocks, which, once published, cannot be altered. This technology's transformative probability is huge when it comes to city management. To unveil this potential, administrative teams and mayors must learn how blockchain systems' attributes can help with their management duties. Subsequently, other professionals from the city governance, such as jurists, economists, municipal corporation executives, and architects must also try and evolve their knowledge pertaining to this technology. The primary aim of these stakeholders is to abundantly offer local benefits of this blockchain system to society.

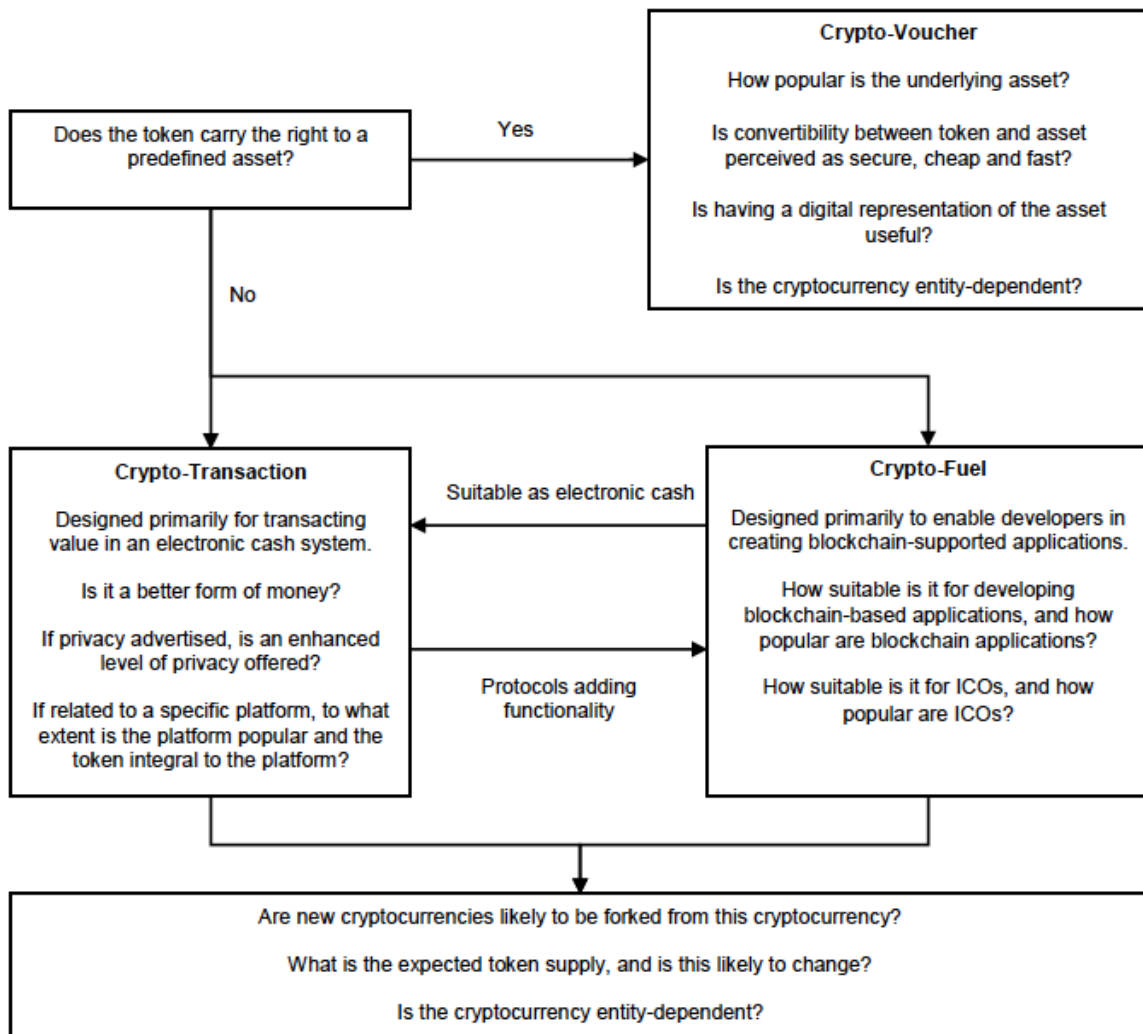
Blockchain technology can conveniently allow the many distributed autonomous organizations (DOAs) that exist in cities to manage tasks and disperse them among all involved parties (22). This approach propagates a decentralized approach to governance and is the solution to several rising sociodemographic problems. According to data, the planet is predicted to have an urban future as present trends show that people are moving to cities in large numbers. By the year 2025, approximately 70% of the entire global population will reside in urban areas, making the urban lifestyle the prime driving force behind the global economy and, subsequently, the primary basis of unsustainability as well. Water resource scarcity, social inequalities, and pollution are only some of the major problems affecting global stability, and there are various areas where blockchain could be applied, including infrastructure, education, transportation, safety, leisure, and urban life.

Singapore, Gothenburg, and Chicago are examples of cities built from innovations (23–25). Not only are they digitized, but they also have a sustainable and advanced model for urban mobility management, citizen participation, waste treatment, and energy efficiency. Smart cities like these have produced the United-Nations-supported initiative Blockchain4Cities (26). This working

group is challenged with finding ways to apply the blockchain concept in smart cities. In the beginning stages of this research, 26 experts from around the world participated. The initial results showcased blockchain’s possibilities in municipal governance due to its ability to securely transmit information without intermediaries.

Many locations are experimenting with blockchain and cryptocurrencies using DAOs to provide new methods of investing and payment. In response, many governments are considering introducing their own digital currencies. State governments also have become increasingly involved in regulating cryptocurrency. It is worth noting that most of these currencies have been transaction-based tools delineated as *crypto-transaction* tokens since they work as a cash substitute or as *crypto-fuel tokens*, which are designed to develop applications (for example smart city or metaverse environments) (27). A decision-tree for understanding these currency or token variations is shown in Figure 3.

Figure 3. An Assessment Framework for Cryptocurrency



Source: Burnie, Burnie & Henderson 2018.

A simple example of the delineation between *crypto-transaction / crypto-fuel token* and *crypto voucher tokens* would be the many in-house reward programs businesses currently have. For example, the Chuck E. Cheese family entertainment and pizza chain allows users to play games and earn tickets in their facilities. These tickets can only be spent within their entertainment centers. While these tickets are more akin to *crypto-transactions* and *crypto-fuel tokens* if they were based on the amount of energy produced while bouncing in a ball pit which power the video games where tickets were earned, they would be more akin to *crypto-vouchers*. Likewise, if the games played powered a higher-level gene sequencing or war game simulation a case could be made that they are *crypto-vouchers*. The St. Regis Hotel has recently accepted a cryptocurrency that represents future stays and is backed by hotel ownership; akin to a timeshare.(28) Some highlights of where these activities are occurring are in Table 2 and the subsequent profiles.

Table 2. Summary of Government Adoption of Blockchain and Cryptocurrency

Government	Central Government (Yes/No)	State Government (Yes/No)	County Government (Yes/No)	City/Municipal Government (Yes/No)	Other Government Agency Authority (Yes/No)	Use - As Currency (Yes/No)	Use - In Smart Contracts (Yes/No)	Use - Blockchain or Security (Yes/No)	Use - in Decentralized Finance/DeFi/ Bond or Debt Issuance (Yes/No)	Launched (Yes/No/ Unclear)	Physical Manifestation (Yes/No)
US - States	0	39	0	3	0	30	0	20	32	31	1
	out of 44	out of 44	out of 44	out of 44	out of 44	out of 44	out of 44	out of 44	out of 44	out of 44 (7 unclear)	out of 44
Other Countries	56	0	1	7	1	5	0	79	72	66	0
	out of 100	out of 100	out of 100	out of 100	out of 100	out of 100	out of 100	out of 100	out of 100	out of 100 (18 unclear)	out of 100
Canada States	0	8	0	0	0	0	0	8	9	4	0
	out of 12	out of 12	out of 12	out of 12	out of 12	out of 12	out of 12	out of 12	out of 12	out of 12 (4 unclear)	out of 12
Canada Cities	0	13	0	13	0	0	0	13	14	5	0
	out of 17	out of 17	out of 17	out of 17	out of 17	out of 17	out of 17	out of 17	out of 17	out of 17 (8 unclear)	out of 17
US Major Cities	0	62	0	108	0	100	0	106	114	103	0
	out of 166	out of 166	out of 166	out of 166	out of 167	out of 168	out of 169	out of 170	out of 171	out of 172 (12 unclear)	out of 173

Wyoming

On April 21, 2021, Wyoming Governor Mark Gordon signed Bill 38, allowing the state to legally DAOs as limited liability companies (29–31). Generally, DAOs make governance decisions and implement certain actions through the use of blockchain-based “smart contracts” (i.e., pieces of computer code that execute specified functions when given certain data). DAOs do not have centralized managers or executives. Wyoming’s law requires that a DAO be registered through an agent and include proper designation in its articles of organization (self-

identifying as a DAO, a DAO LLC, or an LAO (limited liability autonomous organization), and it ensures that a DAO's members will not be held personally liable for the debts and liabilities of the company, addressing concerns that a DAO could be construed as a partnership.

San Francisco

Unsurprisingly, the technology capital of the U.S. figures prominently in our examples. San Francisco is the home to cryptocurrency trading platforms Coinbase and Kraken. More than a hundred merchants accept bitcoin, from restaurants and bars to hostels and stores. There are 437 bitcoin ATMs in the Bay Area, including 65 in the city of San Francisco itself, which is impressive given its relatively small population of 880,000.

Portsmouth, New Hampshire

Portsmouth is home to a surprisingly large community of cryptocurrency users. Dubbed “bitcoin village” by local residents, the downtown area is home to around a dozen crypto-friendly businesses, including the Seacoast Repertory Theatre and the Free State Bitcoin Shoppe. There are also 21 bitcoin ATMs and tellers in Portsmouth and nearby towns—a surprisingly high figure for a town of only 22,000 residents.

Miami, Florida

Miami has approximately four dozen merchants who say they accept bitcoin and a surprising 651 bitcoin ATMs and tellers. It is also home to the Miami Bitcoin Conference, one of the oldest and largest conventions of the cryptocurrency industry. The city's government wants to attract blockchain businesses to their city, and Mayor Francis Suarez has proposed investing city funds in bitcoin and even launching a municipal cryptocurrency

New York City

New York City's 8.4 million people can spend their bitcoin at approximately three dozen merchants in the metropolitan area, including the Bitcoin Store in lower Manhattan and CryptoART in the Morningside Heights neighborhood. New York City is also an important hub for crypto startups and media companies, such as CoinDesk, Decrypt, and CoinTelegraph, as well as home to Consensus, one of the largest annual events in the crypto industry.

2.4 Cities have the Ability to Leverage Lessons from the Past

Looking to historical examples may provide cities some comfort in exploring new approaches that, in truth, represented methods that were previously accepted and workable. For example, cities may issue their own currencies. As described below, cities and other organizations have issued their own currencies or scrips in the past.

Today, cities issue cryptocurrencies, such as Miami's MiamiCoin (32). As miners create new MiamiCoin, 30% is put into the city's digital wallet. If the value of the coin grows, so do the city's finances. In this scenario, municipal coins are sponsored by city governments and contemplated mined coin in the most conventional cryptocurrency since as digitally mined assets.

First, understanding what mining means in the context of cryptocurrencies is important. Coins are mined as new blocks are added to a currency's blockchain. In order to mine coins, each computer participating on the chain is asked to solve a complex computational task, which typically takes a significant amount of computing power. This task is an example of a "proof of work." The computational work forces the cryptocurrency miner to earn the right to participate in the consensus process to add to the blockchain; adding a block effectively "mines a coin."

Further, in this case of bitcoin, the "proof of work" process is used as a mechanism to make mining coins progressively more challenging in order to constrain supply and prevent the inflation of the currency through oversupply. A decade after bitcoin came into existence, massive computer resources consuming large amounts of electricity are required to mine coins as compared to the small personal computers that were adequate in the earliest days.

The core goal of currencies like Bitcoin is to create a predictable supply that cannot be inflated by a wayward central bank. However, the mechanism by which bitcoin and many other cryptocurrencies achieve this goal is by arbitrarily creating a computational mechanism of no intrinsic value to constrain supply in order to create value through scarcity.

Bitcoin uses proof of work to drive consensus and add to the blockchain. This approach has been criticized as miners are essentially using fiat currencies for electricity to convert into bitcoins. The consumption of electricity for no socially useful purpose is perceived to be environmentally damaging since a significant amount of electricity is generated through carbon emitting mechanisms. The work task is, again, used to earn the right to participate in the consensus process and add a block to the chain and thereby earn a mined coin.

Other cryptocurrencies such as Ethereum (ETH) have tried to shift to a more environmentally friendly approach, called "proof of stake." Here, the right to participate in creating a new block through consensus is randomly assigned to those who have "staked" a certain amount of their held currency to be a part of the consensus process. In other words, a person can indicate that they will receive a certain number of their ETH tokens as lottery tickets for the right to participate in the generation of a new block. The more tokens someone stakes the better their chances are to mine new coins.

As previously discussed, many of uses of these technologies, such as the hash, block, proof of work, consensus, etc., have been substantially different than their original intended purpose to facilitate the development of cryptocurrencies.

Here, we contemplate an alternate approach, where currencies are rooted in a true source of value. That value can be based in useful work or bearing a useful asset. Instead of cities creating coins that are mined in the conventional manner as other cryptocurrencies, cities can generate coins that represent real and useful work or they can represent value in the form of real rights to assets or rights themselves.

For example, the city can issue currency against real rights, such as ground leases. The city can also make payments in its own currency. The right to perform city services can be paid in the city's municipal coin, and the right to perform municipal services can be extended in the form of smart contracts. Cities can transform how they operate using blockchain technology and cryptocurrencies that are rooted in blockchain technology to reestablish trust and transparency.

Municipalities issuing their own currency is surprisingly not novel. To explore this topic, it helps to understand what money actually is, as we explore further below.

2.5 Much of the Money Circulating Today is in the form of Credit

As such, money is a contract. Money is essentially credit that has been extended and a corresponding promise to pay. Some types of money are “bearer assets,” such as cash. Simply having possession of it implicitly gives you ownership rights and the right to use it. Money generated by credit typically is more specific. It denotes who lent the money and who borrowed it. Credit card debt is an example. Banks implicitly are debtors to their depositors when they use their depositors' money to extend credit to others. In the fractional banking system, the bank can lend far more money than it actually possesses with the assumption that all of its depositors will not need their money all at the same time.

With the above in mind, the act of extending credit creates money. Over a century ago, when the general store manager extended credit to a customer, that act created money. Although there may not have been any pieces of paper or coins exchanged, money was ephemerally created. Similarly, when a bartender opens a tab and leaves it open, during the period when the tab is not settled, new money has been created and ephemerally exists.

Today, a significant amount of money is created when the federal government issues more money by purchasing bonds in exchange for federal notes or credit. More specifically, the U.S.'s central bank, or the Federal Reserve, facilitates the creation of money. The U.S. Federal Reserve Banking system has a complex structure that includes participation by private banks.

- The U.S. Federal Reserve is a bank.
- The U.S. Federal Reserve issues currency.
- The currency the U.S. Federal Reserve issues is backed by the assets on its balance sheet.

The U.S. Federal Reserve creates money when it exchanges currency for circulating treasury bills, notes, bonds, or other financial instruments. Money flows from the Federal Reserve to the holders of these financial instruments in a transaction where the Federal Reserve puts these assets onto its balance sheet as part of the exchange. Ultimately, it is a simple transaction where owners of these securities sell them to the Federal Reserve, and the Federal Reserve gives them currency. That currency is an extension of credit by the Federal Reserve. The assets on the Federal Reserve's balance sheet back up the value of that extended credit in the form of currency.

Today, the Federal Reserve is the only bank in the U.S. that is allowed to issue currency. That was not always the case. During the "Free Banking Era" (1837–1863), the U.S. federal government or associated entity, such as the Federal Reserve, did not have a monopoly or significant role in issuing currency (33). The Free Banking Era began when President Andrew Jackson chose not to renew the charter of the Second Bank of the United States.

During this time, state and national charter banks issued their own currency. These banks were regulated in terms of reserves and capital ratios to ensure they were solvent and structurally sound. Regulation was not always well applied and enforced, and so-called Wildcat Banks in rural areas were poorly administered and regulated (33). These banks were at a higher risk of default and injected risk into the overall banking system. Often banks backed the currency they issued with gold or other approved asset types. The assets served as a form of collateral that backed the solvency of the bank. Banks were allowed to "create money" through the fractional banking system, where their deposits could be lent out since all depositors would not need their funds at the same time. Banks pay depositors interest and charge debtors interest as well. The interest charged to debtors is more than to creditors/depositors and this "spread" is how banks make money.

The more money banks can lend, the more money they can make by having more debtors on which the interest rate spread is applied. For this reason, banks have an interest in extending as much credit as possible. Regulators want to make sure banks do not overextend themselves by ensuring they have reserve deposits that can cover any depositor demands. Again, in the fractional banking system, banks are lending out their deposits. They keep on reserve only as much as needed to handle normal depositor demand for liquidity. Banks will naturally want to take this fractional ratio as thin as possible. Regulators ensure that banks remain well capitalized and do not over-extend themselves.

Banks at all levels issued currency in this manner over one hundred years ago in the U.S. But, as with the previous examples of the general store and bar tender, institutions beyond the banks also issued currency. Railroads, general stores, cities, etc. all issued their own currency to promote the usage of their products and services and to promote commerce. They used their underlying assets, such as rolling stock and inventory, to back up the value of the currency.

Figure 4. Ohio Central Railroad Currency



Source: <https://www.ohiochannel.org/video/ohio-currency-the-ohio-railroad-company-2-1845>

Often these currencies were backed by assets, such as rail car rolling stock or the rendering of services. General stores frequently issued credit to promote patronage; department store credit cards are the late- twentieth- century equivalent. Of course, local banks also issued currency. These banks were often “nationally” or “state” chartered, which signaled their degree of regulation and associated stability.

Figure 5. Bishop’s General Store House Ten Cent Note



Source: <https://www.worthpoint.com/worthopedia/bishop-general-store-house-10-cent-459539089>

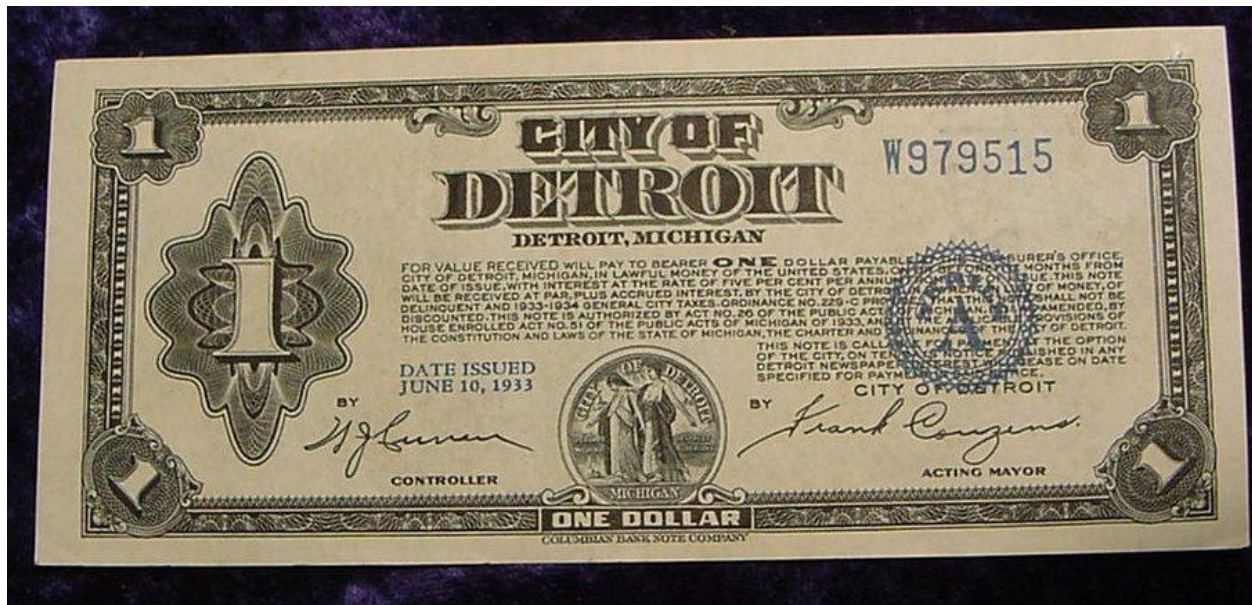
Figure 6. City National Bank of Selma Five Dollar Note



Source: <https://www.antiquemoney.com/national-bank-notes/tennessee/old-money-from-the-city-national-bank-of-chattanooga-1746/>

City governments themselves issued “scrips” as a form of legal tender, which were often used in remote areas where other currency was not available. These scrips (or “chits” in India) were a form of credit or money. One benefit of scrips was to keep money in the local economy because they were usually only accepted locally or further away at a discount. Scrips were used by cities, such as Detroit during the Great Depression, to facilitate commerce and extend credit when other forms of credit and liquidity had evaporated.

Figure 7. City of Detroit One Dollar Scrip



Source: https://www.icollector.com/1933-City-of-Detroit-Mich-Depression-Scrip_i8482621

Scripts are not a “thing of the past.” Countless communities in the U.S. still issue local currencies (34). For example, Bristol Bucks are sponsored by the city of Bristol, Vermont in collaboration with a local bank.

Figure 8. Bristol Bucks



Source: <https://bristolcore.org/bristol-bucks/>

These local currencies are sometimes expressed as “hours” versus dollars, belying their association between value and labor rendered or “work” (35). The City of New Orleans issued three different currencies in the first half of the 1800s.

Figure 9. City of New Orleans \$20 Dollar Note



Source: HNOC <https://www.hnoc.org/virtual/money-money-money/municipal-currency-new-orleans>

These municipal- issued currencies were largely replaced by nationally chartered bank notes at the end of the Free Banking era, which were, in turn, replaced by Federal Reserve Notes at the inception of the Federal Reserve system in the early 1900s. All of these older currencies were backed by precious metals such as gold or silver; a material that people believed was real and authentic. A real asset had to act as a common medium of exchange.

With blockchain technology delivered agreed- upon services, rights, and other assets can be predefined to act as those underlying assets that the currency can be backed by. Blockchains can combine with smart contracts to create real work or a conference of rights that creates true proof of work and true proof of state to create value and generate new coin that is mapped to that underlying value created. This concept is discussed in more depth later in this document.

Cities can create DAOs in which they act as currency- issuing and managing entities similar to banks. Citizen- created entities can also be represented in the form of DOAs that can coordinate through the Autonomous Community Ecosystem, discussed in the next section, that leverages smart contracts across DAOs.

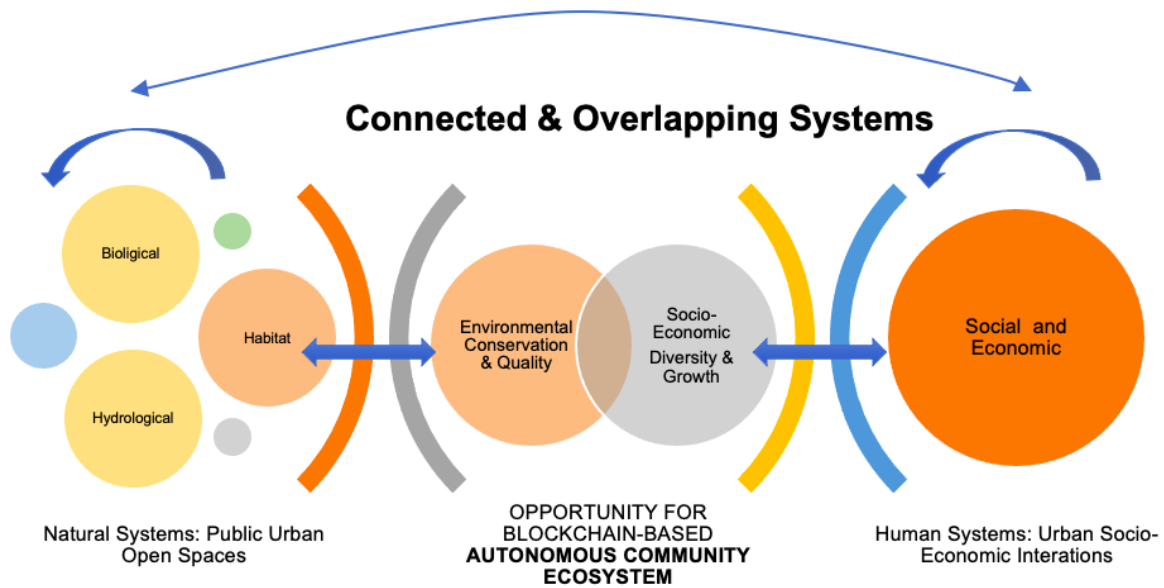
2.6 Opportunities for Autonomous Community Ecosystems

While experimentation with DOAs is a first step at achieving self-organizing systems that use the basic principles of blockchain, the structure does not perfectly match to urban systems. In many urban environments there is a closely-knit relationship between natural systems with their human counterparts. These natural system affects the human system by providing ecosystem services, heat island relief, etc.; the human system affects the natural system through the use of these services and their related health and social benefits.

It is in this overlap of human and ecological systems where communities face pressure points and embedded tension (36), yet they are complementary systems and not competitive. At the time DOAs and most government systems are inherently competitive, so do not reflect complementary and complex node-driven networks. Governments, particularly, have linear workflows that do not reflect they the complex and integrated systems of the natural world. This calls for integrative community-based ecosystem approaches to deliver infrastructure and services that balance economic prosperity, social cohesion, and ecological integrity.

In this context, key questions arise on how organizations can develop new Autonomous Community Ecosystems that match how natural systems are net with built, social, and economic systems. How can these networks work more integratively? How can new technologies like blockchain provide self-organizing structures that balance economic prosperity with ecological sustenance? How can government systems become more reflective of what communities and neighborhoods want? These framing questions form the basis of thinking about blockchain can be applied to communities going forward in this document.

Figure 10. Connected and Overlapping Systems



Note: Diagram illustrating overlapping human and ecological systems and opportunity for Autonomous Community Ecosystems to serve communities in self-organizing networks that deliver infrastructure and services in improved ways over existing governing structures.

3. Specifications and General Process Flow for Municipal Blockchain and Decentralized Applications

As referenced earlier, the general process flow for blockchain architecture involves: 1) the creation of blocks (transactions); 2) the sending of these blocks to nodes (users) on the network for an action (mining) and then a validation that that action has taken place; and 3) the addition of the block to the blockchain. (See Figure 2) Financial remuneration can be part of this process as a demonstration of economic- value creation based on the mining action / work completed. This is done using set of rules known as a “consensus protocol” that establish the processes and standards by which this workflow is completed (37).

While there are different ways of assigning this value, in our case, we reference a value that is physical in nature as opposed to the notion of currency trading that has been popularized through cryptocurrency. This is referred to as crypto-token or crypto-voucher since it carries the right to a predefined asset— again, something of physical value supporting the financial value creation (27). This is also consistent with new forms of cryptocurrency such as Helium and Climatecoin, which link their value to ability to provide Wi-Fi converge that supports things such as e-scooter connectivity and emissions reduction (38).

Any new record or transaction within the blockchain implies the building of a new block. Each record is then proven and digitally signed to ensure its genuineness. Before this block is added to the network, it is verified by the majority of nodes in the system, which supports the validity of the value that is created and potentially awarded after work is completed. In this context, specifications for decentralized application (DApps) and stable coin- linkage can be established as a standardized platform for use by public agencies for transportation application. This can provide a self- sustaining, customizable platform that provides verification service delivery in novel ways that support new visions for DAOs; what we refer to as ACEs.

3.1 A General Process Flow for Community-Based Blockchain

As organizations use blockchain to better allocate resources and deliver services, there are opportunities to support communities in creating more positive urban environments. This can enable urban streets and spaces to be more accessible, productive, attractive, and better utilized, involving resource allocation through several key concepts:

1. Transactional rights to access / opportunity / property governed by unique tokens— rights to access resources, micro-contracted work, or development
2. Validation or proof of “true” work through smart contracts that create currencies backed by true sources of generated value (community mining activities)

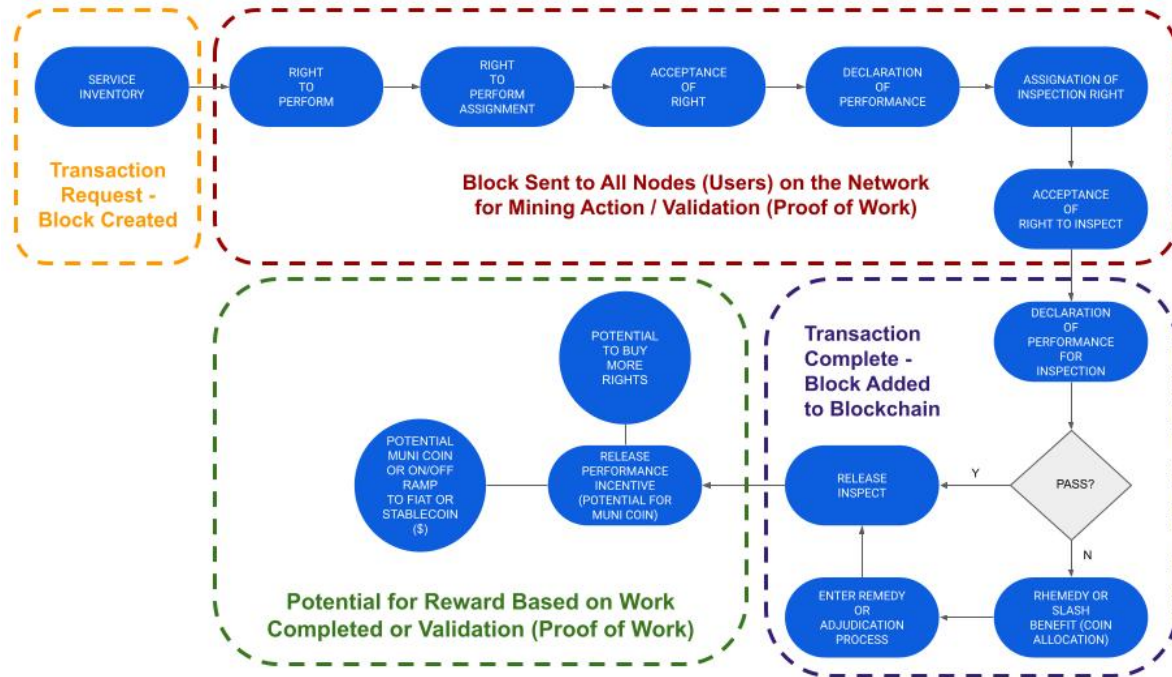
3. Ability to track “true” work through distributed smart contracts that rely on a chain of work and corresponding verification (validation actions based on consensus)
4. A potential for backstopped crypto-voucher, reward, or currency based on work completed and deriving value from the activity occurring or the tax base of the issuing entity that has increasing credibility due to its tax base improving through more intelligent investment

This is illustrated in the Figure 12 that outlines a general workflow for resource or service inventory allocation. This process could be used for a variety of things, for example allocation of municipal land and permitting, but also delivering better services such as graffiti abatement resources. Broadly, U.S. cities contain vast areas of poorly utilized urban space that represent low- value use.

Figure 11. Potential for Graffiti Abatement



Figure 12. Detailed Process Flow Diagram for Municipal Blockchain Activities



As previous sections demonstrated, this can involve creating local currencies backed by the fiat currencies provided by local governments. Leveraging a local currency model, states and local governments can redirect investment to locally relevant projects and opportunities. On this topic there are a few important points:

1. States cannot issue their own currency per the regulation that emerged at the end of the Free Banking Era (see Background section);
2. However, cities can issue their own currency;
3. A hybrid system maintains relevance of a central bank as a lender of last resort, but creates competing stores of value that may appear less debased to certain segments of the market.

The challenge, however, is that:

1. Local currencies are often only usable within specific geographies—during the “wildcat” period, currency “far from home” was often heavily discounted;
2. Needs fiat backstop to have legitimacy;
3. Needs a digital and physical infrastructure.

This last point illustrates the fundamental distinction that likely forms the future of municipal *crypto-voucher* frameworks and distinguishes it from other currency speculation—to a large

extent municipal coin must be backed by physical assets or tangible long-run value creation. This is consistent with the delineations of *crypto-vouchers* from *crypto-transaction* tokens (which function as a cash substitute) and *crypto-fuel tokens* (which underpin application development). This distinction between crypto asset types also emphasizes the importance of providing a **digital representation of the physical asset** – a “phigital” asset in the token environment. While this moves somewhat beyond the scope of this current piece of work, here are some examples of its application:

1. NFT used to deed land use “rights to develop” or to engage in a certain activity
2. Representation that a state or city approves or provides basic improvements and blockchain on NFT assures “compliance of execution”
3. Potential for visual representations of trading NFT rights by trading digital asset
4. Returns on NFT and pivots to *crypto-transaction* tokens provided in local currency to spur more local investment more efficient than
5. Micropayments can be full- freight, unsubsidized, or fully-funded by the government

Yet all of this is a function of constructing the workflow in the blockchain and building a created a privacy-based environment with rules that reinforce trust, but also provide for verification. Ultimately, these ecosystems must be a place where security, transparency, need for coordination of unbounded entities, and trust (or lack of it) comes together. The verification or proof of work provides the glue or critical win where organizations can 1) distribute rights, 2) have multiple distributed mechanisms of validation of work, and 3) have validation of work that creates financial (and potentially social) economic value.

3.2 Specific Applications and Use Cases

Urban Greening, Tree Planting and Mobility / Curb Management

One specific application of the general autonomous community-based ecosystems outlined in the prior section regards urban greening. For many years, academic literature has shown the benefits of integrating the natural environment in urban areas— from the macro-scale influences on local heat and climate conditions to the micro-scale connections to active lifestyles, health, and biophilia (39–44). These studies illustrate the overlap of human and natural systems in urban areas. Green space and human interactions are sometimes addressed separately; however, in urban spaces the lines between the two become more blurred—one clearly impacting the other.

The literature has also revealed the utility and importance of assessing urban settings in an integrated manner that views human and natural systems as an interacting whole (45–52). While such research is complex, it shows the connected and overlapping systems that exist between the

natural and human—reflecting the networks and nodes that can be well-served by autonomous community ecosystems.

Some work comparing the social, economic, and ecological value of open spaces in the Seattle area found that relative value varied based on location along an urban gradient (53). Additional work looking at a lack of environmental quality, suggests that increasing green street infrastructure is tied to reduced socio-economic prosperity and high minority concentrations (8, 54–57).

Figure 13. Potential to Better Utilize Street Spaces Could Lead to Value Creation as Well as Beautification in Addition to Having Potential Traffic-Calming Benefit



China, specifically, has been a leader in this space, engaging in tree-planting at scale. Large portions of the country have been planted and new “sponge cities” are emerging as approaches to climate adaptation (58). On streets and adjacent parcels, this means providing an opportunity for tree-planting at scale. Specifically, though most cities engage in street planting and beautification slowly through public works departments or through inefficient over-the-counter paper permitting processes for citizens who want to engage in the urban greening / beautification process, there is little incentivization to do so and no formal way to validate the benefit to carbon sequestration or urban canopy through feedback loops that could be easily verified.

In this example, we think about how a decentralized neighborhood-based ecosystem that provides the possibility for a crypto-voucher economy for communities to create greener infrastructure can be effective. Studies have already documented that the intrinsic land- use value of streetscape and transit investments can lead to a +5 –8% in value creation (59–63), but the literature has not yet fully explored if on- street improvements that support walkability and bike-ability have the same impact, bolstering property values and the municipal tax base.

As Figure 14 illustrates, citizens can create service requests identifying opportunities where rights of work performance that “mines” this value of a beautified, more productive, or carbon-sequestering streetscape. Figure 15 and 16 apply this to application framework that would write blocks to a distributed ledger. Once the request is approved and work assigned, the service request could be performed by the individual / node making the request or another node on the network part of the same ACE. Table 3 indicates how this process is differentiated from traditional planting / street greening processes. Incentives and / or tokens (in crypto or fiat currency) can be provided back to either party for work completed once that work is documented and entered into the blockchain ledger. There is also the potential that tokens or mined value could go back to a municipality based on some percentage of token ownership that a city or municipal entity might keep as a regulatory overseer. Figure 15 provides a specific illustration of how this might pragmatically work for a streetscape beautification application, where a mobile application framework or platform supports the ACE from an infrastructure delivery, proof-of-work / verification, and value-creation proposition.

The same flow can be applied to many other use cases, particularly where the government has applied a regulatory framework to networks. These regulatory frameworks can work to reduce any potential negative impacts of individuals being “crowded out” by larger groups, while providing more efficient and timely solutions to what individual actors or independent nodes through cities want on a daily basis.

One example is a neighborhood where kids play in the street. All of the neighbors might want it to install a speed hump / table to slow down the speed of traffic, but there is no mechanism to approve or pay for that type of infrastructure in cities. Neighbors could form an ACE around the issue, self- fund, and install the bump, and the city engineer could verify all of these steps through blockchain. The value of the infrastructure could be tied to the value assigned to local properties. The same could be performed with local stop signs, installation of solar or street our detailed example of encouraging street tree planting or micro agricultural uses.

Table 3. Old Process for Street Tree Planting vs. New Process Where Automated Workflow and Distributed Labor Provide Efficiency

Old Process: City Tree Permitting/Planting	New Process: Distributed Neighborhood-Based Tree Permitting/Planting/Tracking
<ul style="list-style-type: none"> • Citizens fills out paper applications for tree-planting location selection and permissions • City reviews paper application • Citizen schedules USA to ensure no utilities • City conducts onsite inspection of location • Permit issued • Citizen purchases or city provides and it is planted <p><i>NOTE: This old process ONLY represents the public right-of-way (not private property) so it does not represent the entire tree canopy. Also there is normally very little verification conducted that tree has been planted according to permissions, or post-reporting to assess the environmental impact or health of the tree — most notable how much carbon the tree is sequestering over its life-cycle.</i></p>	<ul style="list-style-type: none"> • Citizen goes in to blockchain based planting platform and snaps a picture of potential location • Notice goes to city for inspection of location / photo • City approves or doesn't approve (digital permission issued w/ potential NFT); can assign another inspection that can be community crowdsourced • Tree is planted and documented via location / photo verification* • City can inspect to make sure it's done or can assign another inspection that can be community crowdsourced* • Tree registered into tree inventory for master data on canopy / supply* • Carbon / community value created (sequestration, property appreciation, etc.)* <p><i>*Automated workflow provides service benefit not currently provided by most cities</i></p>

Figure 14. Detailed Process Flow Diagram for Municipal Blockchain Activities Related to Urban Greening and Curb Allocation

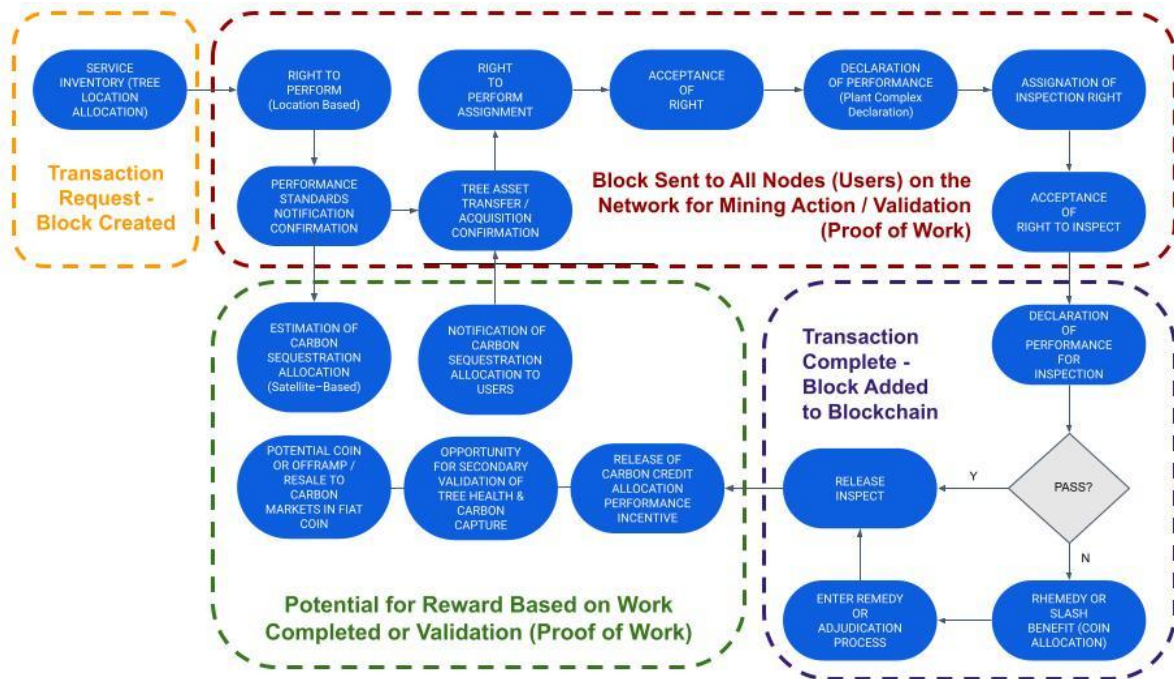


Figure 15. Specific Application Framework for Blockchain Based Tree Planting Use Case

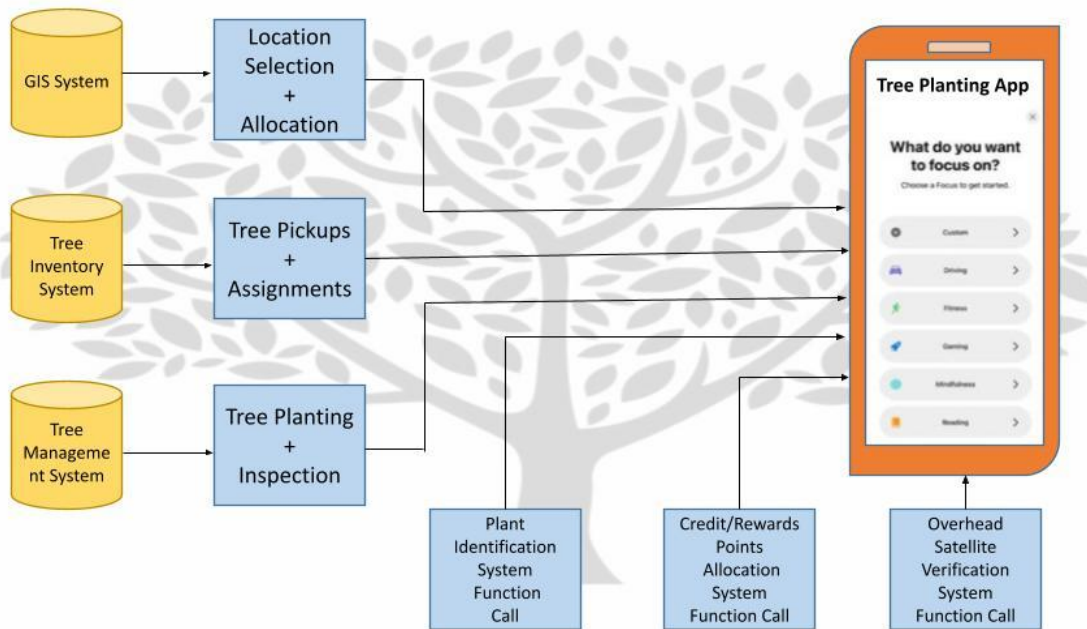
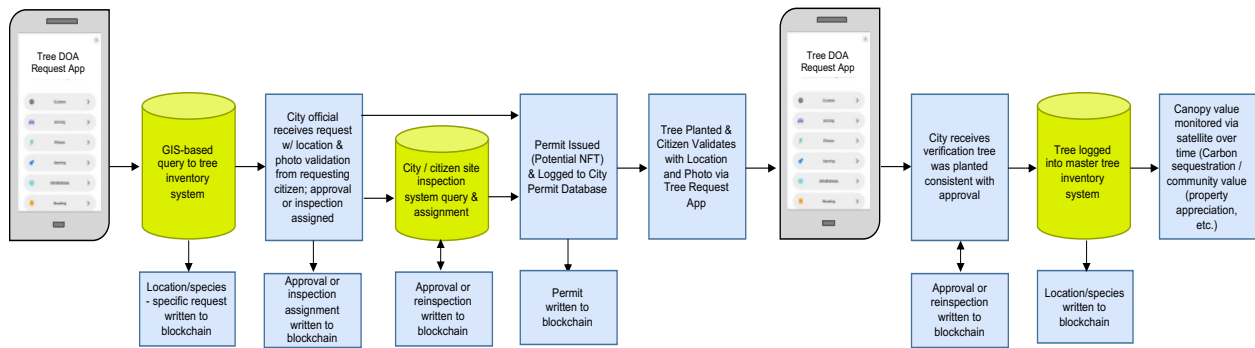


Figure 16. Alignment of Process Flow for Municipal Blockchain Activities Related to Urban Greening and Curb Allocation with Application Logs to Distributed Ledger



3.3 Assignment of Token Value

Assignment of tokens or rights to an asset or type of work can occur across a network. Individual nodes or people could hold these assets along with cities. Asset valuation for tokens can be assigned based on the value of the work / mining action or the right conferred. For example, if a tree-planting right is assigned, value could relate to a percentage share of the price of the carbon sequestration. Conversely, a portion of potential land value appreciation could fund or provide a financial backstop for mining action / work completed. Cities could potentially acquire more tokens than individuals / nodes in order to avoid crowding out and tribalism. There is also the potential for a reward / incentive funded by individual node holders, based on their task assignment apportionment based on assignment of rights based on number of tokens owed.

3.4 Neighborhood Services

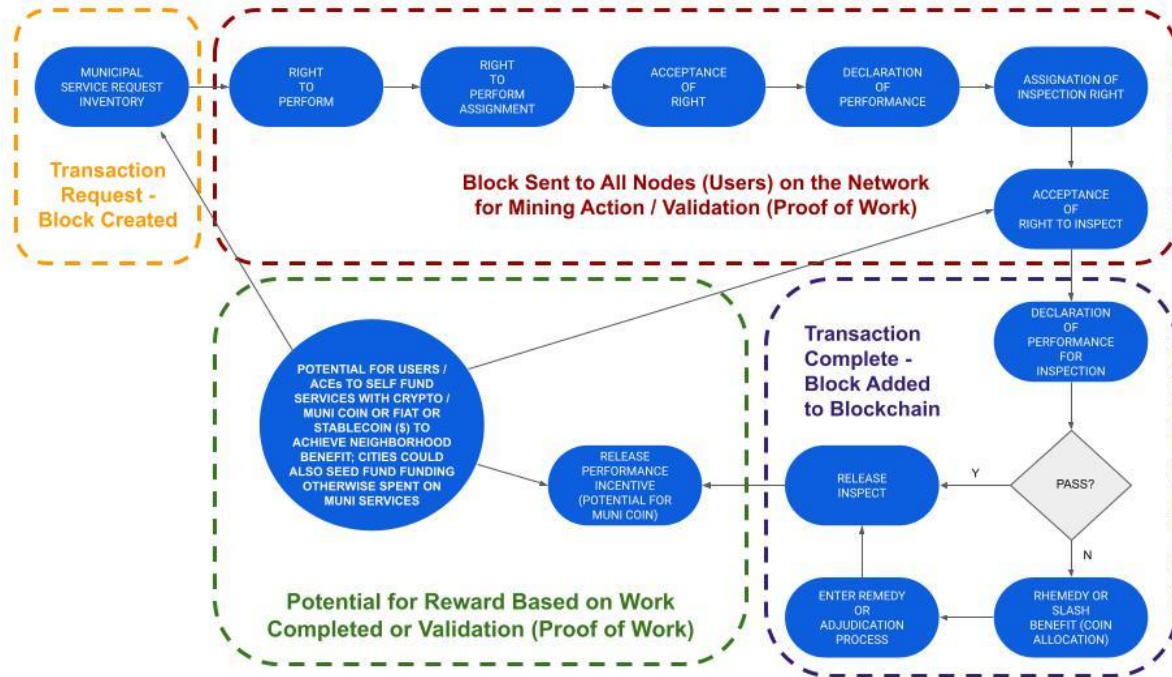
In addition to opportunities for street infrastructure / asset allocation, blockchain technology also allows for street cleaning, graffiti or weed abatement, and other municipal services to occur in a more localized and disaggregated format. Similar to tree planting or curb allocation, in theory, an ACE could develop a service inventory and then engage in rights assignment, mining action, and verification to complete a city's essential work. A citizen concerned about trash on their block could issue a request after which individuals that are a part of the ecosystem can receive the right to perform the cleanup, which can be validated and inspected by other users / individuals.

DAOs or individual users could self- fund these services in crypto-vouchers or a fiat / stablecoin to help drive incentives and achieve the desired neighborhood outcome. This "mining activity" (engagement in a service to a community) could also be initiated by cities to drive local neighborhood community development. Rather than engage in large and fairly opaque contracts for municipal services, cities could invest in neighborhoods and build both social and economic capital at the neighborhood level. The combination of workflows could combine the platform approaches of applications such as SeeClickFix or TaskRabbit to funding platforms similar to Kickstarter or Kiva, creating a new ACE segment for urban benefit at the neighborhood level.

Other service applications could include:

- Basic infrastructure maintenance (signage, roadway striping, infrastructure, light posts, etc.) that may need validation by a local regulatory official, but can be completed by a lay individual.
- Transit / ride service allocation between individual transit agencies and rideshare companies that supplement and compliment transit. This aligns with the “trust and verify” approach proposed by Tsao et al. (64).
- Bike / scooter system rebalancing; a non-blockchain based version of this is being used by Lime with the “juicer” program and by New York’s Bike Angel program (<https://citibikenyc.com/bike-angels>).
- Last mile logistics or deliveries, where individual customers are incentivized to make deliveries on a local network for neighbors instead of companies— UPS, FedEx, or DHL.
- Homelessness services, where individual neighbors offer to provide wrap-around services for local homeless shelters or supportive housing.
- Elder care, dog walking, or childcare service requests.

Figure 17. Process Flow Diagram for Municipal Service Applications



3.5 Urban Development & Land Use Allocation

Moving beyond transportation rights and municipal service applications, cities apply new ways of thinking about real estate assets. Since 2015, planners and engineers have discussed how autonomous vehicles offer a new way to view street space allocation. This could mean novel ways of distributing rights of ownership and use for right-of-way (8, 65–69). Referred to as right-of-way re-allocation, this could allow for,

Cities could conduct “right-of-way recapture” and then choose to repurpose that for bicycle or pedestrian infrastructure, or for gardens and play areas. They could also consider deeding this real estate back to private owners for them to do what they please—an action that would not only increase property value for owners but municipal property tax revenue on an annual basis. (70)

Blockchain and broader adoption of DAOs could enable this land use allocation and permitting in a way that offered flexibility, while rebuilding trust and providing opportunities for use validation through unique nodes on the network. In such scenarios, *parking spaces could be allocated for other uses: including parklets, gardens, play areas for children and even front yard accessory dwelling units (ADUs).*

Just how might this work? As an example, a municipality could designate plots in 10 meter by 10 meter allotments for micro development. Using a token construct, the city could provide a contractually potential for a service request to assigning micro development rights to claimants via an open marketplace. The allotment could be developed in accordance with the contractually

defined parameters of the token (the consensus protocol) with a defined NFT conferred along with the development. If token obligations (development rights) were met, the NFT (proof of work) could be retained. If it is not met, the token could be revoked.

Blockchain oracles, through mechanisms such as aerial / satellite imagery, could confirm compliance with token obligations along with in-person site visits. For example, as indicated in Figures 18– 20, Google Street views could be used to identify latent demand that could be eligible for regeneration or intensification. As shown in Figure 21, this land allocation process through ACEs could occur on private or civic properties, providing the identification and development of vacant and underutilized land in new ways that supports housing, food, and energy production. This framework of rights allocation could also apply to topics such as:

- Energy Production and Pricing
- Carbon and Emissions Accounting
- Recycling and Solid Waste Chain Reductions
- Curb Assignment or Roadway Metering
- Last Mile Logistics or Mobility Platform Distribution / Redistribution

Figure 18. Potential Development Right Allocation Site 1



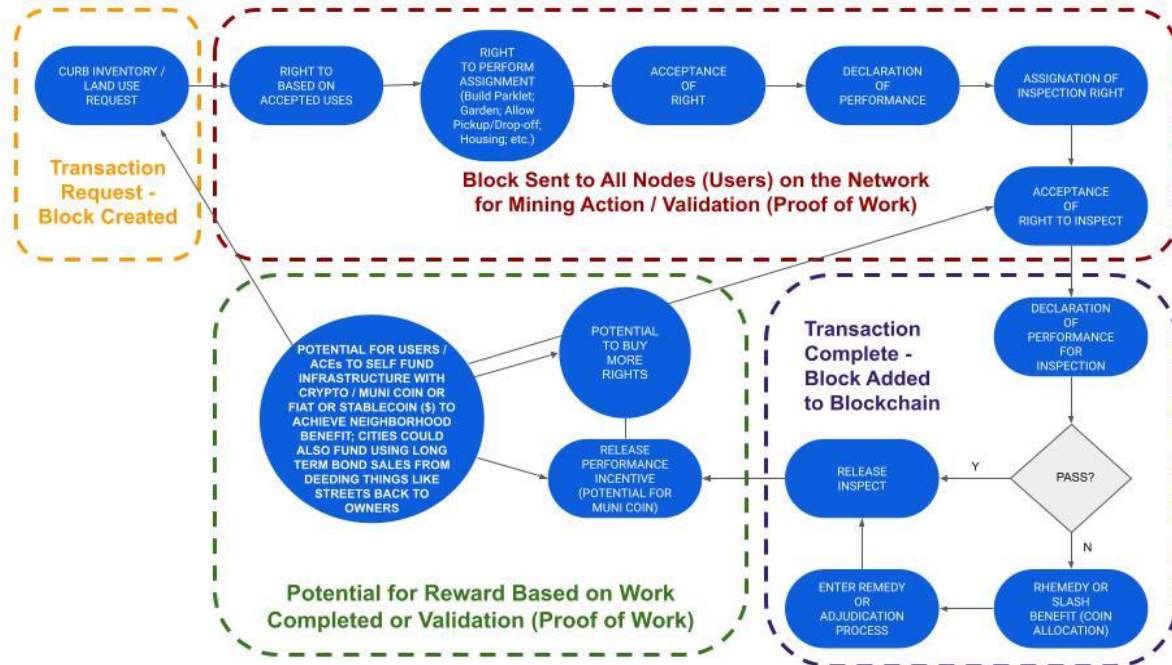
Figure 19. Potential Development Right Allocation Site 2



Figure 20. Potential Development Right Allocation Site 3



Figure 21. Detailed Process Flow Diagram for Urban Development Applications



3.6 A More Detailed Outline for ACE-based Street / Land Rights Assignment and Development

A basic outline of what this kind of blockchain activity could look like is articulated below. The process flow diagram that follows the outline provides a simpler pathway that could be used for the conversion of excess street, right of way, or parking.

1. ACEs, citizen groups, or government identifies assets to be developed.
2. Government verifies basic infrastructure: right of way; access; electrical, water, sewer.
3. Land is turned over to a Development Authority with the city retaining 100% equity interest with a multi-party board. Developed land is deeded to the authority as an NFT for the underlying land as an asset.
4. Parcels are allocated by bid as NFT s for “deed for development.” Deed for Development is effectively a long-term ground lease. Parcels may be 10x 10- meter micro-development sites.
5. Smart contract is used to determine:
 - a. Time to complete development
 - b. Specifications of allowable development

- c. Inspection allocation and results
 - d. Rights of resale and associated NFT claw back for percentage of gains back to the authority
 - e. Rental or usage parameters
 - f. Conditions for forfeiture of right
 - g. NFT carries with it the potential rental contract terms or use contract terms (if an NFT owner wants to occupy it themselves or rent it , t he NFT terms create parameters for renting and also govern how the developed property can be rented. The NFT/smart contract parameters also govern the currency in which rental payments can be made— for example, in a local currency only).
6. NFT Deed for Development owner completes development.
 7. NFT Deed for Development holder completes development.
 8. NFT Deed for Development holder rents property back to the authority that can then rent it to the city to use for homelessness abatement or other purposes.
 9. OR— NFT Deed for Development holder rents property to open market renter and creates generally affordable housing.
 10. Infrastructure Bank is part of the created Authority. The Infrastructure Bank enforces collection of rent and other activity in the form of local currency.
 11. Currency is backed by value created by developed property.
 12. Currency helps to contain inflation of housing stock and keep as much money in local economy as possible. Local currency can also be used to establish local economy for critical goods and services.
 13. Microneighborhood can have different classes of NFTs for goods and services. Deed of Development can be converted as part of established smart contract for special use such as “micro-stores” that take the place of former corner shops, harnessing existing land uses, perhaps by converting old garages to neighborhood serving businesses (71) or allowing for more opportunities for food trucks or the influx of on-street or curbside dining, as was seen during the COVID 19 pandemic (See Figure 22).

Crypto or fiat value could come either from the group of citizens forming AVEs or from government entities themselves who strategically deed public land to private ACEs upon request and then bond against the potential increase in property tax from the deeded square footage.

This borrows from the basic principles of Tax Incremental Finances (TIFs), where the value of future improvements or up-zoning of land is used to finance infrastructure that supports the public good.

Figure 22. San Francisco On-Street Dining



Source: SF Planning Department <https://www.flickr.com/photos/sfplanning/50567861163/in/album-72157715102556516/>

4. Additional Use Cases

As illustrated, this new technological platform creates an opportunity to think about how to empower citizens and governments to create change in their own backyards. Decentralized finance (commonly referred to as DeFi) has recently been discussed as a part of blockchain-based cryptocurrencies such as Ethereum, Bitcoin, and Dogecoin, yet the principles of decentralized and independent software platforms to allow for lending and finance have much broader application potential. Many brokerages, exchanges, and banks are exploring offerings using decentralized financial instruments that allow for more flexible financing, and the potential for applying these smart ways of assigning rights and financial benefits has much broader application.

A distinctive factor of this pivot to financing is difference how these currencies are valued in the future. As referenced earlier, many established cryptocurrencies rely on a consumption function, while others allow for future establishment of currencies or trading platforms based on energy production . Conversely, a token or voucher- based platform provides a way to value assets on a municipal level and allows for trading and commoditization that can create new local economies in fiat or new currencies.

In addition to these new ways of valuing municipal assets and trading rights using new currencies, the broader application of blockchain can work to rebuild trust in public institutions that has been eroded in recent years. In this document, uses cases have been outlined including urban greening, simple municipal services, and land use allocation, but there are many other potential application areas that span both public and private interests. These are outlined briefly in the tables that follow. While not an exhaustive list, the goal of these tables is to provide a platform for how we can think differently about these structures and systems in the future.

Table 4. Additional Municipal Applications of Blockchain

<p>1. Public Procurement</p>	<p>How blockchain can help: A blockchain-based process can directly address procurement’s corruption risk factors by facilitating third- party oversight of tamper-evident transactions and by enabling greater objectivity and uniformity through automated smart contracts, enhancing the transparency and accountability of transactions and actors.</p>
	<p>Key limitations: A number of hurdles can complicate effective deployment. For example, the easier it is to access and use the blockchain platform, the more vulnerable it is to abuse. “Spamming” or “draining” attacks may cripple a system’s anti-corruption potential by flooding it with useless or malicious information or robbing it of the funds necessary to complete each transaction. Additionally, the blockchain platform may not capture the entire universe of relevant human interactions. If collusion, bribery, or even regular vendor selection continue to occur offline, the anti-corruption potential of blockchain-based procurement will be severely stunted.</p>
<p>2. Land Title Registries</p>	<p>How blockchain can help: Blockchain-based land registries can potentially provide a secure, decentralized, publicly verifiable, and immutable record system through which individuals could definitively prove their land rights. This reduces the opportunity for self-interested manipulation of land rights and increases the resilience of land ownership in general.</p>
	<p>Key limitations: Blockchain technology itself cannot formalize property ownership or solve ineffective governance. Countries with nonexistent, incomplete, or incorrect land registries must painstakingly gather, clean, and digitize the information before a blockchain-based land title registry can function. Additionally, the degree of connectivity and tech-savviness within a population may determine the feasibility of this in the short term.</p>
<p>3. Electronic Voting</p>	<p>How blockchain can help: Blockchain’s decentralized, transparent, immutable, and encrypted qualities could help minimize election tampering and maximize poll accessibility.</p>
	<p>Key limitations: Given the high stakes of elections, electronic blockchain-based voting presents substantial risks. Any new technology systems, including those based on blockchain technologies, are vulnerable to cyber-attacks and other security risks. These could cause vote manipulation, paper trail erasure, or electoral chaos. Furthermore, a voter verification system that uses biometric software, such as facial recognition, could lead to false positives or negatives in voter identification, facilitating a fraud or disenfranchising citizens. Blockchain-based voting systems may also entail privacy concerns. It is imperative that any such service be provided by an extremely vetted technology provider and system.</p>
<p>4. Beneficial Corporate Ownership Registries</p>	<p>How blockchain can help: Many countries are beginning to develop central registries for beneficial corporate ownership in order to better track conflicts of interest and criminal activity. Tamper-evident and broadly accessible blockchain-based registries could provide much- needed transparency and disclosure.</p>

	<p>Key limitations: Corporate ownership registries remain the exception, and those which do exist overwhelmingly lack adequate verification systems. The recent emergence of beneficial corporate ownership registries combined with the novelty of blockchain technology may pose certain challenges to effective implementation. For example, most countries still do not require companies to maintain beneficial ownership information themselves. Furthermore, the adoption of a comprehensive and verifiable blockchain-based registry would require buy-in from politicians, lawyers, banks, and big businesses, many of whom may feel their interests are not served by the public transparency and auditability of such a system.</p>
<p>5. Grant Disbursements</p>	<p>How blockchain can help: Blockchain can potentially help build public trust in granting systems. The ability to disintermediate the number of actors involved in grant awards and disbursements, while management could streamline the process, reduce costs, and minimize opportunities for illicit financial siphoning.</p> <p>Key limitations: The ability for recipients to effectively manage blockchain-based grant disbursements may prove challenging or limit the depth of transparency. Less technologically savvy or well-resourced individuals and organizations may face discrimination or exclusion from grant disbursement processes if they are unable to use the system. Moreover, a blockchain-based disbursement system does not adequately address the challenge of corrupt practices in the use of the grant itself—an issue that frequently arises in the context of humanitarian aid.</p>
<p>6. Proof of Ownership and Transfers</p>	<p>How blockchain can help: Land transactions and proof-of-ownership requests can burden government agencies with documentation and administrative work. By using blockchain, governments can permanently store asset transactions on items such as land, property, and vehicles on a public ledger.</p> <p>The Georgian government’s land registry department, for instance, pioneered a land registry tool to track land ownership and real estate transactions within the country’s borders. As a result, the government has greater transparency in land dealings, and interested citizens can search a piece of land and obtain accurate information, as all initial and subsequent sales are recorded, time-stamped, and stored permanently. This process also greatly reduces the likelihood of corruption, since the distributed ledger is more secure.</p>
<p>7. Self-executing Contracts</p>	<p>How blockchain can help: Traditional legal-contract execution is costly to both governments and their citizens. However, smart, self-executing contracts, enabled by blockchain, can remove the need for intermediaries and potentially improve contract creation and execution. These contracts are publicly accessible and secure within the network.</p> <p>For example, the Swedish land registry uses a blockchain-based solution for land-title transfers. The disintermediation and removal of notarization through smart contracts have reduced the transaction time by more than 90%. Some industries have tried to create consortiums that use smart, self-</p>

	executing trade contracts over blockchain to improve the flow of goods between various countries.
8. Social-benefits Management	How blockchain can help: Government systems that provide social benefits, such as unemployment, can be misused and infiltrated by certain individuals and groups, such as cyberattackers. Blockchain can improve record management and provide protection, though issues of privacy must be thoroughly addressed. Keeping anonymized IDs and data in employer databases while storing the encrypted hash key (a digital “fingerprint”) in the blockchain can help safeguard data. The Netherlands, for example, uses a blockchain-based infrastructure to administer its pension program, which has the added benefit of reducing management costs, as it is easier to operate.
9. Validation of Documents	How blockchain can help: Governments are consistently looking for centralized cloud-based solutions to validate all of their citizens’ documents, and blockchain could provide a solution. The technology can store hash values of citizen documents on the blockchain, allowing governments to provide an attested and permanently time-stamped electronic version of them anytime. As an example, MIT created Blockcerts, an open standard where apps can be built to issue academic certificates and other documents via blockchain. The Maltese government also used this standard to implement a system whereby its Ministry for Education and Employment can verify any academic credential using blockchain.
10. Patent Protection	How blockchain can help: Since blockchain can permanently time- stamp transactions at any time, companies or individuals can file patents without enduring the cumbersome submission process. While the actual patent verification might take time, the time stamp associated with the filing can help solve multiple patent-related disputes and potentially prevent costly lawsuits. For example, a company could time-stamp a document before it undergoes the full patent application and filing; thus, if a competitor tries to register a similar patent, it is easy to prove which party had the idea first. Furthermore, patent documents are given a transaction hash, providing protection via encryption.

5. Conclusions and Future Directions: Opportunity to Reinvent the Way We Finance and Deliver Urban Infrastructure

5.1 Public Sector Blockchain can Build Trust, Protect Data, and Reduce Costs

Blockchain has quickly gone from relative obscurity to a mainstream topic. Realizing its cross-cutting applicability, hundreds of government leaders have joined the General Services Administration's (GSA) blockchain working group to share use cases and best practices.

Governments have tried to implement blockchain with mixed outcomes. Many had hoped that blockchain would be a game-changer for issues such as security and operational challenges. Indeed, this technology has the potential to help agencies make improvements in many areas, including accelerating the speed of transactions, such as for land-use registries. Often agencies turn to blockchain for lack of another technological solution or because they have been drawn in by the surrounding hype. While blockchain can greatly improve security compared with more traditional technologies, its success hinges on applying it to a specific problem and identifying appropriate use cases. *Finding the right use cases can help agencies realize the technology's full potential.*

We have shown a sampling of applications that can benefit from 1) rights distribution, 2) validation of work, and 3) validation of work that creates financial (and potentially social) economic value. Informed by the success of global agencies using blockchain, we have defined use cases that illustrate how governments can unlock the technology's full potential. These include:

- Urban greening for streets and parcels: tree permitting and planting along roadways
- Commercial agreements and contracts for street / municipal infrastructure: street sweeping, pickup, garbage collection, bike / scooter system rebalancing
- Land Rights Allocation and Development for things such as parklets, on-street dining, and even housing / homelessness services.

But these distributed systems can help balance trust with verification and help achieve four clear benefits of the technology for cities and neighborhoods:

1. Building Trust with Citizens
2. Assigning Disaggregated Rights More Transparently

3. Reducing Costs & Improving Efficiency
4. Protecting Sensitive Data While Providing Validation

Since blockchain's utility depends on stakeholder adoption, government agencies can use economic incentives such as providing free access to certain government data or offering federal credits to reduce transaction service fees to attract users. Agencies that successfully implement blockchain could increase citizen trust and generate value for both the government and its citizens.

5.2 Yet Blockchain is not a Silver Bullet

The technology has yet to reach widespread adoption at scale. Too often, organizations fail to assess potential barriers and rush into implementation. Below are a few examples of challenges that government agencies could experience at the outset.

While blockchain's pseudonymous transactions can protect a person's real identity from being discovered, many governments need to securely verify a user's identity to process a transaction. Governments could integrate blockchain with digital IDs or implement private and permissioned blockchains (used in trade and certain financial contracts), but these can be complex or lead to privacy issues. For example, if Social Security benefits are tied to a digital ID, they are no longer pseudonymous. In some cases, government agencies need full anonymity, as with voters' ballots.

Moreover, although blockchain is often touted as providing strong security guarantees, this depends on the size of the ledger: smaller ones are more susceptible to manipulation. Indeed, it is possible for an entity or hacker to gain control of a majority of the ledger's node network (the 51% rule), which could create fraudulent transactions.

5.3 The Regulatory Environment is Evolving

As cryptocurrency and blockchain based application grow in popularity, opportunists will attempt to take advantage of consumers. Fraud, theft, and scheme have risen in the cryptocurrency universe. Regulators will want to assure that financial instrument consumers are adequately protected. The Federal Trade Commission received nearly 6,600 complaints in just the 6 months between October 2020 and March 2021 (72). The problem is so significant that the Federal Trade Commission has set up a website to help consumers understand and navigate the issue (73).

At the same time, regulators will want to ensure that taxes on gains are appropriately levied and that the crypto/blockchain universe is not used to evade legitimate taxation. Transactions considered "investment contracts" represent securities where traditional tax laws can be applied. The IRS has determined the cryptocurrencies such as Bitcoin (BTC) are taxed as if they are investments or property (74). As such, if consumers hold onto these cryptocurrencies for more

than a year, they will be subject to lower long-term capital gains taxes versus ordinary income taxes for positions held for less than a year. However, the Securities and Exchange Commission (SEC) considers cryptocurrencies currency and not investments.

The SEC's position on various parts of the cryptocurrency and blockchain ecosystem have been evolving. Recently the SEC expanded the size of its division looking at cryptocurrencies and renamed the group the Crypto Assets and Cyber Unit (75). The SEC effectively ended Initial Coin Offerings (ICOs) as mechanism for companies to raise capital by ruling that these offerings were effectively securities and were required to comply with traditional securities law. The SEC also clearly communicated that DAO based tokens were also subject to this interpretation of securities law. A current case against Ripple Labs which has not yet been adjudicated will provide further clarity on the SEC and the court's thinking.

Current SEC leadership as of 2022 is signaling that tools for decentralized finance, non-fungible tokens (NFTs), and stablecoins may come under the SECs scrutiny (76). When trying to understand the applicability of securities law, the SEC generally applies the Howey Test. The Howey test is named after a 1946 Supreme Court case SEC v WJ Howey Co. where investors could buy citrus orchard land and lease it back to the Howey company who would manage the land and its agricultural output. The SEC argued that this arrangement violated the Securities Act of 1933 and the Securities Exchange Act of 1934.

The case led to the creation of the Howey Test which requires four characteristics to be met for an arrangement to be considered a security that would merit regulation. These four characteristics are:

1. An investment of money
2. In a common enterprise
3. With the expectation of profit
4. To be derived from the efforts of others

These conditions can be refined to consider the following four conditions:

1. The existence of an investment contract
2. The formation of a common enterprise
3. A promise of profits by the issuer
4. The use of a third party to promote the offering

Currently, cryptocurrencies do not meet the Howey Test. However, the SEC's position continues to evolve and new frameworks may emerge from current litigation and guidance. This evolution is likely given the Howey Test is now nearly eighty years old and from a different era. A more complete guidance is provided by the SEC in its Framework for "Investment Contract" Analysis of Digital Assets (77).

In the case of traditional cryptocurrencies, the first condition is met because traditional or fiat currency is used to purchase tokens. The formation of a common enterprise is hard to assert in the blockchain world given the decentralized nature of the operation. In addition, there is no promise of profits by the issuer. Finally, cryptocurrencies do not meet the fourth condition since there is typically no central actor promoting the security.

As such, from an IRS perspective; taxes on gains from cryptocurrency trading are treated like gains on other security or currency arbitrage. For the moment, the SEC views cryptocurrency as neither a security nor a currency but instead as a commodity. These perspectives may change as mentioned above given the quickly evolving landscape.

Further, the approach contemplated in this paper also behaves more as a "scrip." A scrip does not compete with the national currency and is instead primarily used for the exchange of goods and services. As such the tokens and non-fungible tokens contemplated in this paper more closely resemble local alternative currencies or scrips.

In the state of California, the state legislature has clarified that these local alternative currencies are legal and encouraged. The California Alternative Currency Act (AB 129) was passed in 2014 in the wake of the Great Recession. Similar laws were passed in France around the same time (78). The law was meant to clarify section 107 of the state Constitution which stated, "No corporation, flexible purpose corporation, association or individual shall issue or put in circulation, as money, anything but the lawful money of the United States." With this clarification, innovations such as the one discussed in this paper are not only legal, but encouraged.

5.4 How should Governments Proceed?

As blockchain evolves, it continues to show promise as a disruptive force for governments. To optimally deploy this distributed-ledger technology, government agencies should take three steps:

1. Identify the problem being solved and provide enough detail to define a business case, including the key performance indicators (KPIs), participant incentives, the technology compatibility, and the required investment. This process should ensure that blockchain is the simplest and best approach to solve the problem.

2. Develop proofs of concept and blockchain infrastructure for the most obvious use cases (such as time-stamping and validating documents or executing peer-to-peer transactions with minimal mutual trust). Benefits might include quantitative KPIs, such as the costs reduced or incentives generated, as well as qualitative KPIs, such as transparency, which can affect rankings such as the ease-of-doing-business index.
3. Once the benefits are apparent, scale the existing use cases and apply the technology to other more complex use cases, such as processes involving multiple entities and data sets. Governments should strive to achieve all possible benefits and help scale blockchain across the organization. To develop and manage blockchain effectively, organizations will require a larger pool of employees who can successfully execute software development.

5.5 Future Opportunities: Embracing ACEs

The broader context and future opportunities of this work involve exploring micro experiments in applying a new structure on top of DOAs and most government systems that reflect complementary and complex node-driven networks— we frame these as *autonomous community ecosystems*. These integrative community-based ecosystem approaches to delivering infrastructure and services can potentially create distributed ways of helping do work and build infrastructure. ACEs are a new segment or category of technology that combine many of the lessons from peer-to-peer work and micro-finance applications and combine them in a disaggregated self-organizing environment that reflects natural systems, akin to biomimicry. Use cases can range from rights allocation to planting trees or engaging in development to conducting services such as street clearing or weed abatement. By using blockchain to empower citizens, it can rebuild the erosion of trust in civic institutions.

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